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THE TACONIC MOUNTAINS OF NEW ENGLAND

by

Myrtle Lavina Wilcock

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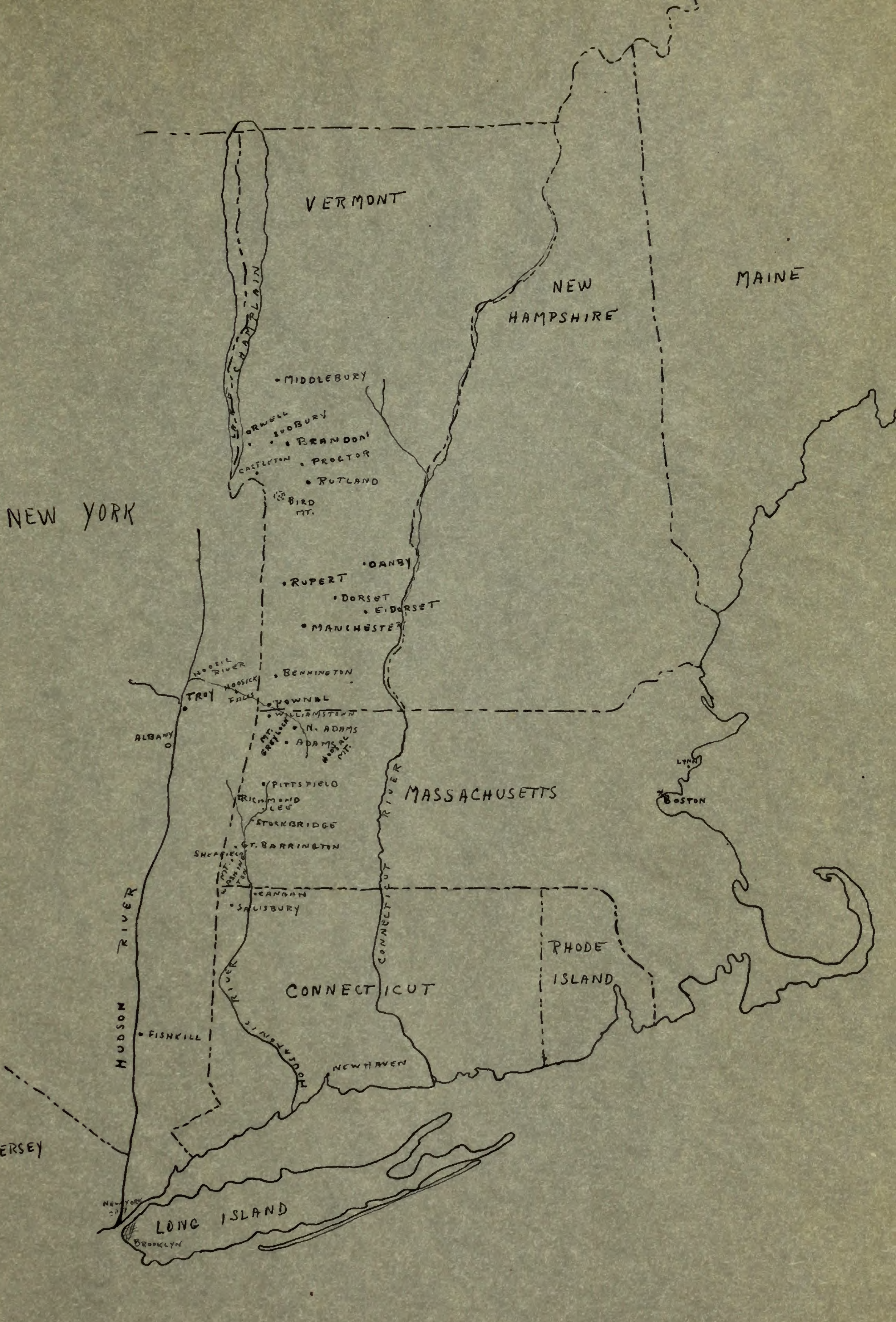
THE TACONIC MOUNTAINS OF NEW ENGLAND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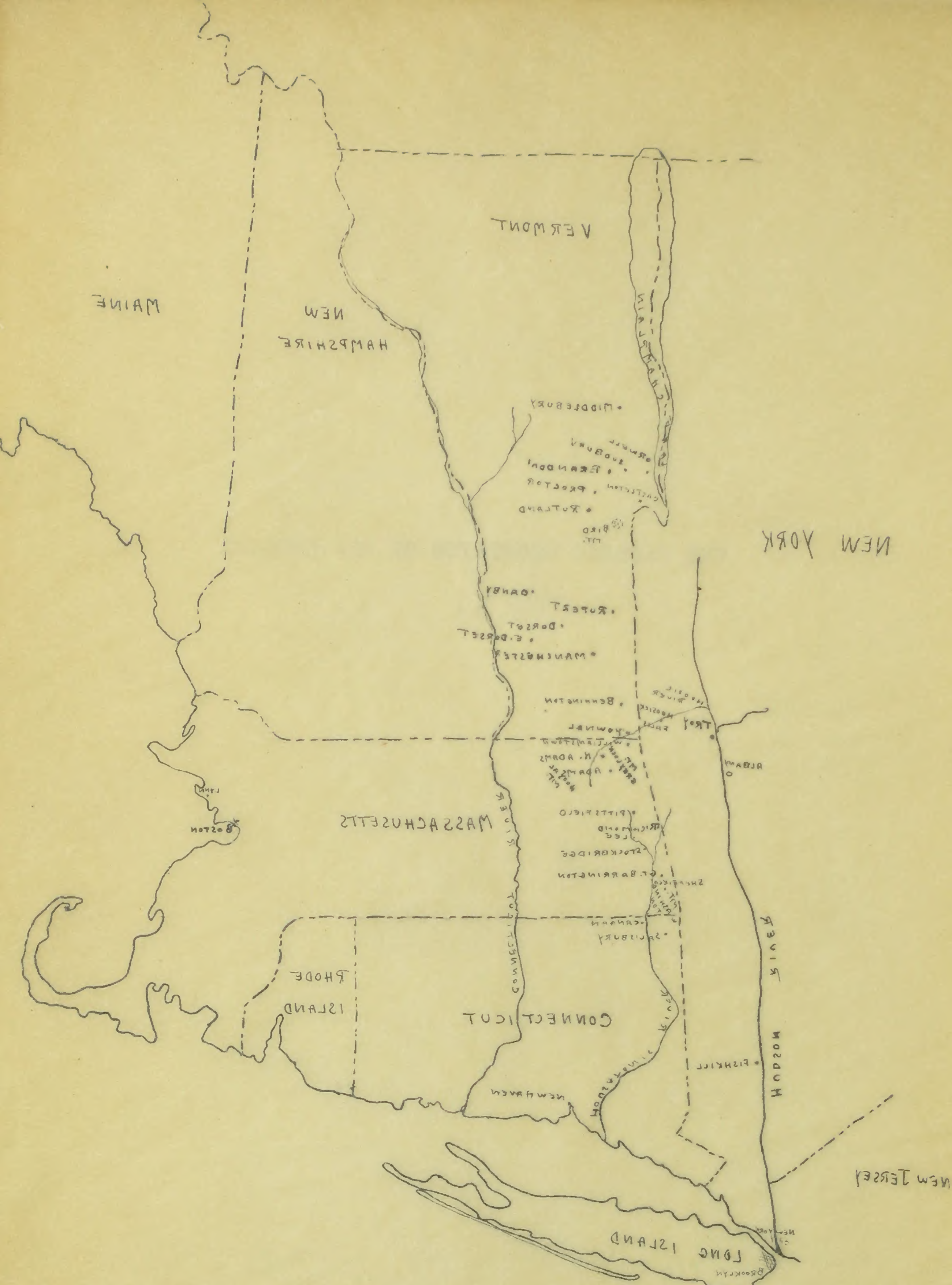

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INTRODUCTION

Location of the mountains

The Taconic, or Taghkanic, Mountains are a low mountain range on the western border of New England and the eastern boundary of New York State. They extend from the Highlands east of the Hudson River in a north-northeasterly direction, and they gradually become higher as they enter Massachusetts and Vermont. The general trend of the range is very nearly that of the western New England boundary, that is, about N 15° E along the western border of Massachusetts, and about N 5° E along the Vermont boundary. On the north they connect with the Green Mountains in the region of Middlebury in Central Vermont. On the south they gradually dwindle to a low narrow strip south of Salisbury in northwestern Connecticut. Their length is about 200 miles.

Purpose of the thesis

My purpose has been, not to do any original field work myself nor to draw any new conclusions from work already done, but to survey the literature on the subject and from it to write a general description and history of the region.

Detailed descriptions of stratigraphy and structure will not be given, for there can be no advantage in copying long excerpts from easily available original sources. However, descriptions sufficient to give the general reader an understanding of the stratigraphy and structure of the region will be included, and reference made to the best works for further specific details.

A complete history of the development of the Taconic region through geologic time has never been written heretofore, so far as I have found in the course of my reading. This history I shall attempt to write, using material from all sources available. This will constitute the major portion of my thesis.

Lastly, the economic features of the region will be touched upon briefly.

Résumé of earliest literature on the subject

The geology of the Taconic region is particularly complex. Because of its proximity to their colleges, it soon attracted the attention of the early geologists of the East. Benjamin Silliman is recognized as the first important American geologist, but he did little more in the Taconic region than to make some observations of the rocks and minerals.[1] He did no thorough research work there. He did, however, stimulate intense interest in the region.

In 1816 Professor Amos Eaton heard two of the courses on Mineralogy and Geology given by Professor Silliman at New Haven. The next year, full of enthusiasm for the subject, he began a series of lectures at Williams College, with the result that "an uncontrollable enthusiasm for Natural History took possession of every mind; and other departments of learning were for a time crowded out of college. The college authorities allowed twelve students each day (72 per week) to devote their whole time to the collection of minerals, plants, etc., in lieu of all other exercises."[2]

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1. Silliman, Notices of Minerals and Rocks chiefly in Berkshire. (Full names and titles of all references hereinafter made will be found in Bibliography A.)
2. Quoted from Mr. Eaton by Dana, Berkshire Geology, pp. 3-4.

In 1817 Professor Eaton left Williamstown, leaving the special study of the region in the hands of Dr. Chester Dewey. In 1818 Dewey published in the first volume of the Silliman Journal (now the American Journal of Science) the first of his articles on the Taconic region, entitled Sketch of the Mineralogy and Geology of the Vicinity of Williams' College, Williamstown, Massachusetts. The "Taconick Hills" first took their place in geological literature in this paper. He speaks of the hills of the "Taconick" range, and in a footnote says, "Former orthography Toghconnuck and Toghconnuc. That of the text deviates farther from the Indian, but is later and preferable."[1]

The article consists of a description of the hills and a list of the rocks and minerals found there. These include granite, gneiss, mica slate, quartz, granular limestone, and others. The paper also includes the first geological map of the region, an enlarged copy of Carleton's map of this part of the State, with one or two corrections. This map shows merely the relative situation of the streams and the principal hills and mountains. An attempt to show by coloration the localities of the various kinds of rock is made in a cross section of the

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1. P. 337.

region, but not on the principal part of the map.

In 1820 Dewey followed this first paper with another one on a Geological Section from the Taconick Range, in Williamstown, to the City of Troy, on the Hudson, which appeared in volume 2 of the Silliman Journal. An article in 1823 showed a much widened range -- A Sketch of the Geology and Mineralogy of the Western Part of Massachusetts and a Small Part of the Adjoining States, illustrated with a colored map embracing all Berkshire, the southern portion of Vermont, Canaan and Salisbury of Connecticut, and eastern New York to the Hudson.

Dewey was a Neptunist, and so his principal rocks of the region include granite, gneiss, mica-slate, primitive limestone, primitive argillaceous slate (or argillite), transition limestone, transition argillite, and graywacke. He was attempting, by using these terms, to make the facts here conform with those described by English and European geologists. His long list of minerals followed the order and names in Cleaveland's Mineralogy (2d Ed.), based on the Linnaean biological classification.

The colored map showed the north-south direction of the belts of limestone and the Taconic backbone of the region.

Dewey was a chemist, and he determined

rightly that the composition of the prevailing slaty rock of the Taconic range is chiefly aluminum. Thereupon in all his published papers he called the rock "very fine grained mica slate". However, these slates were called talcose slates by other geologists because, like talc, a magnesium mineral, they felt greasy. They refused to accept Dewey's determination and the error continued in geologic thought both in America and in Europe for over forty years.[1]

Dewey wrote other articles on the subject of the Taconic region. All are interesting and important historically, but are of no practical value today.

Professor Edward Hitchcock, another important early worker in the field, published his Final Report on the Geology of Massachusetts in 1841. His later study of the region enabled him to improve greatly on Professor Dewey's maps and descriptions. Hitchcock gives an especially graphic description of Mt. Greylock, and he was the first to locate, roughly to be sure, the boundary between the lower limestone and the lower schist of the mountain. This Report was published one year before the announcement by Professor Emmons of his Taconic system, and so it has nothing on that subject.

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1. Dana, Berkshire Geology, pp. 4-5.

The Taconic controversy up to Dana

Professor Ebenezer Emmons, with whose name the "Taconic System" will always be associated, commenced his geological investigations in 1833, when he was appointed Professor of Natural History at Williams' College. He became one of the most active geologists of the country.

The "Taconic System" was first conceived by Professor Emmons in 1841. In 1842, in the Report on New York Geology, he clearly defined the system. The account covers pages 113 to 164 of the volume.

Emmons studied the positions and distribution of the rocks of the Taconic region. He distinguished an eastern belt of limestone, which he called the Stockbridge limestone, and a western belt, which he named the Sparry limestone. He observed that all these rocks, and also the quartzite of the region, had an eastward pitch or dip, and hence he concluded that they were all of one system. He observed that they had no fossils. He found what he believed to be evidence that the fossiliferous slates of the Hudson River Valley overlaid unconformably the upturned Taconic slates. The conclusion he reached, therefore, was that this non-fossiliferous Taconic series was older than the Hudson River slates; older than the oldest known rock of the New York Silurian, the Potsdam sandstone, and therefore a

distinct system of rocks, the Taconic system.[1] He put this series between the Adirondack rocks, or Archaean, and the Potsdam sandstone, the rock directly overlying the Archaean in northern New York.

The name of the Taconic Mountains immediately began to attract the interest of geologists in both Europe and America. The system was extended from Maine to Georgia and divided into Upper and Lower. Some geologists favored the system; others absolutely refused to accept the claim of the Pre-Silurian age of the system. Prominent in the first discussion were Professors Henry D. Rogers, Edward Hitchcock, and William W. Mather, and Mr. James Hall, all of whom objected to the views of Emmons, and Mr. Lardner Vanuxem, who favored them.[2] In 1860 Barrande, the eminent paleontologist of the Silurian of Bohemia, entered the field. He adopted and developed the views of Emmons but not in a way which pleased the latter.[3]

In 1861 Professor Edward Hitchcock, his son Charles H. Hitchcock, and Mr. A. D. Hager published the Geological Survey of Vermont, which contained a statement of the discovery in the limestone

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1. Dana, Berkshire Geology, p. 6.
2. " , Brief History of Taconic Ideas, p. 412.
3. Ibid., p. 419.

of fossil corals, crinoids, mollusks, etc. of Lower Silurian age, in the towns of Danby, Dorset, Sudbury, and others.[1] Similar and additional discoveries were later reported by Rev. A. Wing of Vermont. This finding of Lower Silurian fossils in both the eastern and western Taconic limestones was fatal to the Taconic system.

The controversy, however, was not yet ended. Discussion went on continuously. A few of the men who wrote frequently on the "Taconic System" and the "Taconic Question" may be mentioned: Joachim Barrande, James Hall, Charles H. Hitchcock, T. Sterry Hunt, Arthur Keith, Jules Marcou, Samuel A. Miller, William B. Rogers, Richard P. Stevens, Charles D. Walcott, Alexander Winchell, and Newton H. Winchell.

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1. Dana, Berkshire Geology, pp. 7-8.

Work of James D. Dana

In 1871 Dana entered the field of controversy, and continued his studies of the Taconic region until about 1890. He stated in several articles that in his opinion, according to his study of the region, Emmon's geological reputation stood uninjured despite the fact that his Taconic system had to fall, for he was right in his observations. It was further discoveries which proved Emmons to be wrong in his conclusions.

Due largely to the careful work of Dana, chiefly areal but partly structural, and also to the discoveries of fossils in Vermont localities by Rev. A. Wing, and the work of Charles D. Walcott, a paleontologist of the United States Geological Survey, it was at last proved that the Taconic system was not a "Pre-Silurian" system, but merely a synonym for the older term "Lower Silurian".[1] "Lower Silurian" has, since Dana's day, given way to the term Ordovician.

The great controversy, which lasted over forty-five years, thus passed at last into history. It served very useful ends, however, for it directed attention to this important and complex region of North America and promoted investigations of wide bearing and influence.

All work earlier than that of Dana may

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1. Dana, Brief History of Taconic Ideas, passim.

today be passed over as being of no practical value. This is due not to any lack of ability on the part of these early workers, but to the fact that their work was carried out upon wholly inadequate conceptions.

During his years of study of the Taconic region Dana wrote many articles on many phases of the subject. The majority of these were published in the American Journal of Science. He established the fact of the synclinal structure of both the Mt. Greylock and Mt. Washington masses, as well as of the adjoining smaller ridges. He showed the continuity of the limestone of the valleys and the fact that it is the underlying rock, and the continuity of the schist above the limestone. Although his work has largely been replaced by later writers, chiefly T. Nelson Dale and William H. Hobbs, Dana is nevertheless one of the important figures in this particular field. It was upon his work that the rest built, fundamentally, and they have replaced him largely because of the application of structural principles not yet formulated in Dana's day.

The Taconic region is very complex. In 1892 Elkanah Billings wrote that on account of the extremely complicated structure of the rocks, no

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The Taconic region is very complex. In 1892 Elkanah Billings wrote that on account of the extremely complicated structure of the rocks, he

man living would see a perfect map of the Taconic region.[1] This is as true today as it was then, but workers still are striving toward that end.

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1. Gordon, Studies in Geology of Western Vermont, (1st Paper), p. 116.

DESCRIPTION OF THE MOUNTAINS

Physiographic

General features

It may be stated here that frequent reference will be made to the topographic maps which are enclosed in the envelope at the end of this thesis. For convenience of reference these have been lettered A, B, C, D, and E.

A few miles to the west of the Green Mountain range there stretches a series of long, narrow ridges and irregularly-shaped mountain masses. These rise above the 1500 foot contour level. As they near the 2000 foot level they become narrower and more irregular. Only a few of the summits rise above 2500 feet. These masses constitute the Taconic Mountains. The range extends from near Fishkill on the Hudson River, in New York State, to a point two miles south of Brandon, Rutland County, Vermont, where, geologically, it ends. However, as the northern part is more or less merged in a hilly belt extending four miles beyond it, the range may be said, physiographically at least, to extend almost to the Addison-Rutland County line.[1]

In general the trend of the range is north-northeast, but its course is somewhat serpentine.

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1. Dale, Geology of the North End of Taconic Range, p. 185.

In Great Barrington and Stockbridge, Massachusetts, it is north-northwest. From there to Dorset, Vermont, it is quite uniformly north-northeast. From Dorset to Castleton Cut it is north, and from there on it is again north-northwest.

In the vicinity of Adams, Massachusetts, the distance across the range and its spurs is twelve miles. In the northern part of Bennington County, Vermont, it is about ten miles, while in Addison County it is only four or five miles.[1]

The Taconic range is divided into several series of mountains and ridges which are separated by deep lengthwise valleys and cross-gaps or passes. The range shows a very noticeable development of single peaks. While the summits at the north are more uniform than those at the south, there is, on the whole, a greater variety of summit heights in this range than in the other upland districts of western New England.[2] The highest points are Mount Equinox, near Manchester, Vermont, 3816 feet, (Map A), Dorset Peak, near North Dorset, Vermont, 3804 feet, (Map A), and Mount Greylock, southwest of North Adams, Massachusetts, 3505 feet, (Map B).[3] A very prominent feature of the range is the fact that the eastern slopes are much shorter and steeper than the western.

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1. Dale, Taconic Physiography, p. 19.
2. Keith, Topography, p. 12
3. Dale, Taconic Physiography, p. 18.

There are five main transverse valleys: (1) The valley of the Hoosic River, which extends down to the 800 foot contour level, and which has a northwest-southeast course diagonal to the general trend of the Taconic range. A little south of the Vermont-Massachusetts line this valley turns and runs eastward for four miles, separating the Greylock mass from the outjutting portion of the Green Mountain range north of it. (Map B) (2) The valley of the Mettawee River, in Pawlet, Rupert, and Dorset, Vermont, running northwest-southeast also, like the Hoosic, but reaching the 800 foot level for only half its course. (Map A) (3) The wide valley of the Walloonsac River in Bennington, Vermont, and Hoosick, New York. (Map B) (4) The valley of the Batten Kill in Arlington, Vermont. (Map A) (5) The valley of Castleton and West Rutland, Vermont. (This last valley is not shown on the topographic maps annexed to this thesis.) The last three valleys have east-west courses and reach the 800 foot level.[1]

The longitudinal valleys of the region are harder to describe, not only because of the complex topography but particularly because some of them have no definite names by which they can be designated. North of the Taconic range, in Addison County, a

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1. Ibid., pp. 19-20.

500 foot rise of elevation separates the valley of Lake Champlain from the Vermont Valley. This Vermont Valley north of Dorset Peak separates the Taconic Mountains from the Green Mountains, but is itself divided into two longitudinal valleys by Danby Hill, Clark Mountain (Map A), Boardman Hill, and Pine Hill (out of sight on Map A). South of Dorset Mountain the Vermont Valley is regular until it reaches south of Bennington, where it is cut across by Mt. Anthony (Map B). When it enters Massachusetts the valley may be said either to follow the Taconic Range proper and to end near South Williamstown, or to merge into the Hancock Valley.

In Massachusetts there are four longitudinal valleys -- (1) the valley along the western foot of Hoosac Mountain, separating it from Mt. Greylock, (2) that which separates the Greylock mass from the "Taconic Spur", (3) the Hancock valley between the spur and the main Taconic range, and (4) that between the Taconic range and the Rensselaer Plateau. (Map B)

South of the Pittsfield Plain the topography is very complex. There are, however, three main longitudinal valleys which merge near Great Barrington to form the Housatonic Valley.[1] (Map C)

The hills of the Taconic region generally have the form of long narrow ridges, with crests which

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1. Ibid., p. 20.

either sag toward the center or which have rounded, dome-like, or obtuse-angled summits. The ridges are often short or roughly pyramidal in outline. The slopes vary from steep concave or convex to very gentle. There are also some plateau-like masses having few peaks and with long gentle slopes. The steeper slopes are generally inclined 30° to 40°, seldom 50°. There are few cliffs, and these are not over 1000 feet, and are usually not over 500 feet in height.[1]

The region is all glaciated, but there is little divergence between the actual rock contours and those of the overlying till, terrace gravels, and clay beds. Such divergence as there is is almost entirely below the 1500 foot level.

The development of the present relief and its drainage system has been almost entirely the work of subaërial agencies, -- the action of streams and of ice, the work of atmospheric agents, frost action, and physical and chemical weathering. The erosion resulted either in the truncation of major anticlines and in the exposure of the limestone along the axes of the folds, or in the minute sculpture of the truncated folds and in the erosion of fault scarps. As soon as this folded region was raised above sea level, rain water began to collect in the synclinal troughs and streams began to flow down the sides of the anticlines. In

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1. Ibid., p. 22.

time the anticlines were reduced to valleys, while the synclines remained as mountains. These are now being drained by streams in the direction of the decreasing folds to the Hudson River Valley. It is apparent from the present drainage lines and from the position of the water-shed of the Taconic range, that the erosion of the Taconic range has taken place chiefly on the west.[1]

Glacial erosion was doubtless of less importance than pre-Glacial. The ice sheet probably aided materially in cutting those valleys, ravines, cuts, ridges, and spurs which have northwest-southeast or north-south axes. However, when the amount of time which elapsed between the end of the Ordovician and the close of the Tertiary is compared with the time allowed for the Pleistocene glaciation, it will readily be admitted that pre-Glacial stream erosion is most likely the principal factor in the erosion of this region.

Among the particular effects of erosion the following forms are prominent in this area: anticlinal hills, synclinal hills, dissected hills, outliers, inliers, anticlinal valleys, synclinal valleys, ravines, fault scarps, and talus slopes.

One effect of Glacial erosion is "rock shattering". The summits of the Taconic Mountains are

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1. Ibid., pp. 34-35.

frequently found to consist of shattered ledges. The initial shattering was by the mechanical action of the glacier. It has since, however, been supplemented by frost action. When these ledges are covered with vegetation they are probably the sources of the higher ice-water brooks and springs which are such a delight in the summer.[1]

The Taconic area is not a region of disorderly hills. In 1895 W. M. Davis pointed out[2] how moderate the inequality of the surface would appear to one standing on one of the hills if it were not for the few peaks that rise above it and the many valleys that sink below it. Its former continuity can easily be perceived. Less easily seen, however, is the lack of agreement between the surface and the rock beneath. However the rocks are inclined, they are cut off evenly when they reach the upland surface. This is an important fact, and upon it depends the correct interpretation of the development of the region.

In general it may be stated that the physically and chemically more resistant rocks form the more elevated portions and the steeper slopes of the region, while the broad valleys and gentle slopes correspond to the areas of the less resistant rocks. The mountains themselves are carved almost wholly from

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1. Ibid., pp. 27-28.
2. Davis, The Physical Geography of Southern New England, p. 271.

slates and schists. The schists are harder than the slates and lie at the east, causing the greater heights of the eastern part of the range. Soluble rocks, such as limestone, dolomite, and marble, underlie the Vermont and Berkshire valleys and the minor valleys within the Taconic range.

Glacial and post-Glacial deposits have modified the ancient drainage. Narrow valleys were choked by moraines and often the deposit of sediment by glacial lakes filled the wider ones. The new streams found much work to do, and in some places rivers were unable to return to their pre-Glacial channels.

The area is well drained. There are two principal rivers, the Hoosic (Map B) and the Housatonic (Map C). The Hoosic flows north and northwest into the Hudson River, while the Housatonic flows south to Long Island Sound. There are several other important rivers, such as the Little Hoosic, Green, Mettawee, Batten Kill, and Walloonsac, to say nothing of innumerable tributaries of varying sizes. A glance at the maps will show the profusion of brooks, creeks, and rivers.

There are seventy-eight lakes or ponds within the entire Taconic area,[1] twenty-one of which are in the Taconic Range itself and the Berkshire and Vermont

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1. Dale, Taconic Physiography, p. 22.

Valleys. The largest one is Pontoosuc Lake, just north of Pittsfield, Massachusetts.

Only one important mineral spring has been noted up to the present time, Sand Spring on the north side of Broad Brook, about one and a half miles north-northwest of Williamstown Station.[1] The spring boils up through white sand and flows four hundred gallons a minute without noticeable variation even during periods of extreme drought. Its temperature is always 76° F. Among the minerals it contains are lithium chloride, sodium chloride, acid calcium carbonate, acid magnesium carbonate, calcium sulphate, aluminium sesquioxide, iron sesquioxide, silica, and sodium carbonate. This mineral content and the water's purity give it valuable medicinal properties for both drinking and bathing. The spring probably comes from a fault and hence has a deep-seated source.

The mean annual rainfall is about 42 inches, but the rainfall varies by 35-40% of this amount between extremes in different years.[2] The mountains are mostly forest-clad, so the run-off is somewhat checked. It is largely absorbed by the glacial drift which covers all but the steep slopes and highest ridges. The great number of perennial mountain brooks shows that the drift and the rocks are effective

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1. Taylor, Water Resources, pp. 132-133.
2. Ibid., p. 131.

resevoirs for the storage of water.

The soil is rocky and thin and rather unattractive for agriculturalists. The considerable relief, however, furnishes excellent water power, although on a small scale, to be sure, and this water power is one of the chief influences in the location of cities and villages. Farmhouses are always located with reference to convenient access to a spring or a brook. The Taconic range is steep and rugged and its upper parts particularly are poorly adapted to settlement. However, the region is famed as a summer and autumn resort for both health and pleasure, for its pure drinking water, its scenic charm, and its rapid mountain brooks all combine to attract tourists and visitors. The passes from east to west and the deep lengthwise valleys make traffic through the range comparatively easy.

The leading towns of the region are North Adams (Map B) and Pittsfield (Map C), Massachusetts, Bennington (Map B), Vermont, Hoosick Falls (Map B), New York, and Canaan (Map C), Connecticut.

Specific divisions for further study

Several writers have given stratigraphic and structural descriptions of various parts of the Taconic region. There is available at present, however, no detailed description of the entire area. The articles which I have found group themselves about three main divisions, -- the Mt. Washington mass in the southern portion of the region, the Mt. Greylock mass in the central portion, and the northern end, in Vermont. As Mt. Greylock has been studied in the greatest detail of these three divisions and as this region is the starting point for all work in the Taconic range, this mass is treated first in all the descriptions which follow. The Mt. Washington mass is considered next in order, and then the northern end, which, because of its great complexity, still presents many stratigraphical and structural problems. For the purpose of rounding out the description of this Taconic region, I have added brief statements concerning the valleys which bound it on the east (which I have called the Vermont-Berkshire Valley for the sake of convenience of reference) and the Rensselaer Plateau which bounds it on the west.

<u>Mt. Greylock mass</u>. The standard work on Mt. Greylock is T. Nelson Dale's <u>Mt. Greylock: Its Areal and Structural Geology</u>. From this I have taken my descriptions of the Greylock mass.[1]

Mr. Greylock with its spurs forms a topographic unit. (Map E) It is separated on the north from Clarksburg or Bald Mountain, a part of the Green Mountain range, by an east-west portion of the Hoosic River Valley. From the river the mass rises 2700 feet in a distance of five miles to an altitude of 3505 feet above sea level. From this height it descends more or less gradually for eleven and a half miles, dying out in gentle waves about two and a half miles northeast of Pittsfield. On the east it is separated from Hoosac Mountain by the valley of the Hoosic River. On the northwest the valley of the Green River divides it from the Taconic Mountains proper. On the west and southwest the valleys of the headwaters of the Green River and of the Housatonic River separate it from East and Potter Mountains.

The eastern side of Mt. Greylock as seen from Hoosac Mountain presents itself as a central mountain mass of elongated but symmetrical form, with subordinate masses of similar shape separated from the central ridge by areas of gently sloping land.

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1. Pp. 133-136.

The western side, viewed from the Taconics, is in marked contrast to the eastern. The central crest descends abruptly for about two and a half miles, and then rises a few hundred feet again. Two spurs about 200 feet lower than Greylock summit project westwardly from the central mass for about two miles. The northerly one, Mount Prospect or Symonds Peak, is separated from the southerly one, Bald Mountain or Stony Ledge, by a deep east-west cut called "The Hopper". This cut has four branches to the east. Across its western foot is Deer Hill. The western side of the mountain south of these spurs is marked by two very regular, horizontal benches of more or less open pasture land separated from each other by a series of ravines parallel to the Hopper. The most northerly one of these is known as Goodell Hollow.

Viewing Mt. Greylock from the south one can see the peculiar saddle shape of the higher portions which has given the mass the popular name of Saddle Mountain. Greylock summit (3505 feet) and Saddle Ball (3300 feet), about two miles apart, are the two humps of the saddle. The intervening portion, which sinks to 2900 feet, is the seat.

Seen from Clarksburg or Bald Mountain on the north, Mt. Greylock shows a central ridge with two lateral lower ridges. On the east is Ragged Mountain, separated from Greylock proper by the Notch.

On the west Mt. Prospect is separated from Greylock by a minor saddle which to the south joins the Hopper.

The area covered by the mountain as thus defined is about sixteen and a half miles by about three and a quarter miles, or about 53 square miles. However, East and Potter Mountains, to the southwest, are structurally part of the Greylock mass. When these are included the mountain mass is about 85 square miles. East and Potter Mountains connect Mt. Greylock with the Taconics proper toward the south. The entire mass appears to belong properly to a series of hills, Mt. Osceola, West Stockbridge Mountain, and Tom Ball, which lie to the east of and parallel to the main range.

We must include in this division Monument Mountain, which lies in line with the Greylock synclinorium but is cut off from it by the broad limestone plain about Pittsfield. It is about three square miles in area and ranges from 1640 to 1710 feet above sea level and from 740 to 950 feet above the adjoining valleys.

Mt. Washington mass. The name Mt. Washington properly applies to all of the Taconic range lying south of the South Egremont-Hillsdale Turnpike (Maps C and D). The region covers an area about fifteen miles in length by four and one-half miles

in average breadth and lies in the States of Massachusetts, Connecticut, and New York. The regularity of the shape of the mass is broken on the northeast by two deep ravines developed by the headwaters of Hubbard Brook.

The name Mt. Washington is also given, and more commonly, to the double ridge composed of Mt. Everett, or the "Dome of the Taconics" (2624 feet), on the east and Bashbish Mountain on the west. (Map C) These ridges enclose a summit plain, a little to the northward of the center of the mass, which has an altitude of about 1700 feet. This plain is about three miles long by about two miles wide. It is surrounded on all sides by a line of peaks ranging from 1900 to 2600 feet in altitude.

This Mt. Washington mass rises abruptly, with a mean slope angle of 20°, from the Copake-Hillsdale Valley on the west and the Sheffield-Salisbury Valley on the east. On the northwest it merges into the narrow ridge of the Taconics. To the south of Ore Hill, (Map D), it also merges into the hills of the Taconics. From here on the hills become smaller and spread out considerably, gradually dying out completely.[1]

<u>Northern end</u>. In Vermont the Taconic Mountains extend up to the vicinity of Orwell, Sudbury,

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1. Hobbs, <u>On the Geological Structure of the Mt. Washington Mass</u>, pp. 717-719.

and Brandon. (See map at beginning of thesis.) All the highest elevations of the range are in Vermont, and most of these higher summits lie along the eastern border of the range. To the west and to the north the elevation decreases. The entire surface is very irregular. The region is well drained by many streams whose branches have cut deeply into the hills, leaving them as a series of peaks and ridges.[1]

Bird Mountain is just one of the many peaks of this portion of the Taconic range, but I mention it particularly because it is one of the few hills of the region which have been studied in detail. It lies seven miles west-southwest of Rutland, in the townships of Castleton, Ira, and Poultney. (See map at beginning of thesis.) It is less than four miles square and is 2200 feet in height. Its unique outlines attract attention. Its northern end is rounded, while its southern face is very steep. This form is doubtless due to the action of the continental glacier. The mountain is almost entirely isolated from its neighbors, but it belongs to a subordinate line of hills parallel to the main Taconic range.

Vermont-Berkshire Valley. The valley region between the Green Mountains and the Taconic Range is part of a valley which extends from Vermont to Alabama

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1. Gordon, Studies in Geology of Western Vermont, (1st Paper), pp. 119-121.

and which throughout is marked by the fertility of its soil and its limonite ores.[1] In Vermont the valley is called the Vermont Valley. Here it is only a relative lowland. It varies in width, being two miles wide near Brandon, a quarter of a mile wide between East Dorset and Danby, and four miles wide near Manchester.[2] (Map A). In Massachusetts the valley goes by several names. Taking the names of the principal rivers of the region, the northern portion is sometimes called the Hoosic Valley and the southern portion the Housatonic Valley, or the region as a whole may be designated as the Berkshire Valley. Most of this valley floor lies between the 700 and 900 foot contour lines. The outline of the valley is very irregular due to the fact that it was worn down along the soft marbles and limestones of the region, and it follows these soft rocks wherever they project, thus forming deep bays in the uplands of harder rocks. It reaches its maximum breadth in the vicinity of Pittsfield. (Map C) South of the Housatonic Valley and still bounding the Taconic Mountains on the east lies the Sheffield Valley (Map C), and south of that, in northwestern Connecticut, is the Salisbury Valley (Maps C and D). These two are usually included in the term Berkshire Valley.

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1. Dale, Taconic Physiography, p. 14.
2. Dale, The Commercial Marbles of Western Vermont, pp. 54-55.

The Berkshire Valley forms a great natural thoroughfare through the highland region of western Massachusetts.

Above the general valley bottom of the Vermont-Berkshire Valley rise scattered ridges or islands of the harder schist of the region. To mention a few, there are Clark Mountain, Danby Hill (Map A), and Mt. Anthony (Map B), in Vermont, and particularly Lenox Mountain, West Stockbridge Mountain, Tom Ball Mountain, and Monument Mountain (Map C), in Massachusetts. Many of the minor irregularities of the region were smoothed out by the glacial deposits of sand and gravel, especially around Pittsfield and Great Barrington, Massachusetts. In some places the glacial debris has produced hills and small ridges.[1]

Rensselaer Plateau. West of the Taconic range is a very irregularly bounded upland above the 1500 foot contour level. It is separated from the Taconic Mountains by the Little Hoosic and Kinderhook Valley. This plateau slopes steeply on the north, west, and south, and ranges down to the 800 foot level. West of the Taconic range at the north and of the Plateau at the south is a broad expanse of minor hills and hillocks under 800 feet in altitude which constitute the Hudson-Champlain Valley.[2]

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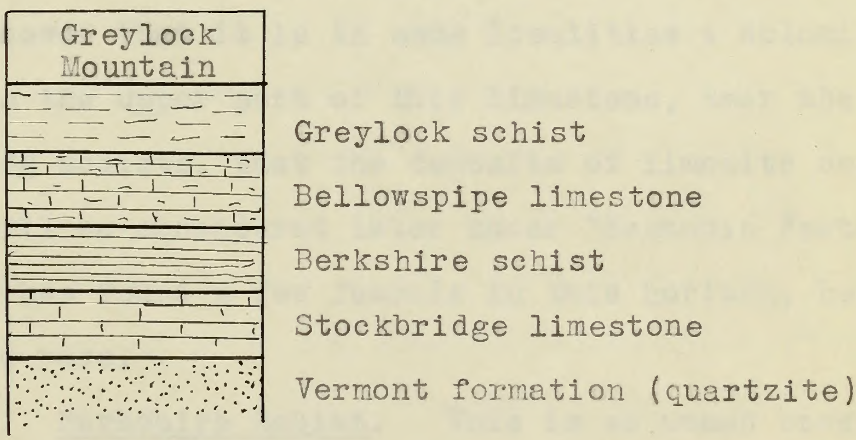
1. Keith, Topography, p. 13.
2. Dale, Taconic Physiography, pp. 20-21.

Stratigraphic

Mount Greylock mass

I have taken for my basic authority for this section T. Nelson Dale's Mt. Greylock: Its Areal and Structural Geology,[1] and the following material, unless otherwise noted, may be considered as coming from that source.

There are five more or less clearly defined horizons in the Greylock mass. Beginning with the lowest they are: Vermont formation (quartzite), Stockbridge limestone, Berkshire schist, Bellowspipe limestone, and Greylock schist. The strata succeed each other conformably, giving a column like this:[2]



Vermont Formation. This is a feldspathic quartzite of Lower Cambrian age. It varies from a fine-grained rock composed to the eye of quartz grains and some mica to a coarse fragmental quartzite or fine-grained conglomerate containing angular fragments of

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1. Pp. 179-190, 200-201.
2. Pumpelly, Geology of the Green Mountains, p. 13.

feldspar and rounded pebbles of blue quartz. It is found in only one or two localities in the Greylock area. It is often called Cheshire quartzite.

Stockbridge Limestone. This is a crystalline limestone of Cambro-Ordovician age, constituting the base of Mt. Greylock. It may be noted that there is no physical break here between the Cambrian and Ordovician strata. This lower limestone is a coarsely or finely crystalline limestone or marble. Its color varies from white to dark grey, and it is often banded or mottled. In places it is so micaceous that it resembles a gneiss. Professor Edward Hitchcock gave five analyses of the limestone of this horizon, which showed that it is in some localities a dolomite.[1] It is in the upper part of this limestone, near the overlying schists, that the deposits of limonite occur. These will be considered later under "Economic Features". Walcott has found a few fossils in this horizon, but they are rare.

Berkshire Schist. This is so named because of its prevalence throughout Berkshire County. This schist, which is of Ordovician age, forms the lower and steeper slopes of the mountain. It consists of the lower sericite-schists. They are made up of intimately interlaced fibers of muscovite (sericite) and folia of chlorite and grains of quartz. Its talcose appearance

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1. Hitchcock, Final Report on the Geology of Massachusetts, pp. 80-81.

and touch have caused it to be given such names as magnesian or talcose slate (Emmons), hydro-mica schist (Dana), and talcoid schist. This talcose condition is due to exceedingly minute folia of chlorite. The difference in the chemical analyses of the schist is due to the varying proportions in which chlorite and muscovite appear in various localities. The color also varies according to these proportions. There are, likewise, variations in the texture. Quartz lenses and seams are almost universal in this schist.

Bellowspipe Limestone. This is so named from its occurrence at the "Bellowspipe" in the notch between Ragged Mountain and Greylock (Map E). This name is given to a series of limestone strata and calcareous (sometimes non-calcareous) schists which constitute the higher benches, the Notch, and Farnham's Quarry area. Although he searched diligently Dale was unable to find traces of this horizon on any of the other higher summits of the Taconic Range, with two exceptions. On Mt. Anthony, near Bennington, Vermont, (Map B), and on Monument Mountain, south of Pittsfield, Massachusetts, (Map C), he found benches which may belong to the Bellowspipe limestone formation, but the relations are not sufficiently clear as yet to allow an accurate determination. Hobbs, however, later showed that the so-called "Egremont limestone" of the

Mt. Washington region is in fact part of the Bellowspipe horizon.[1]

This formation varies from highly crystalline to micaceous, from calcareous to non-calcareous, and from white to gray. Galena, zinc blende, and siderite occur in it. It contains a considerable amount of pyrite grains which have been found to be auriferous, but not sufficiently so to give the rock any metallurgical value. No fossils have yet been found in this formation.

Greylock Schist. All the higher summits of the central ridge and the top of Ragged Mountain are composed of a second series of schists which resemble the lower, or Berkshire, series in petrographic character, appearance, and structure.

All of the above formations show definitely a transitional character. From his study of microscopic sections of these various rocks, J. E. Wolff concluded that this is due partly to replacement and other chemical changes at the time of or subsequent to metamorphism and partly to the character of the original sediments.

Because of the numerous folds, which are sometimes compressed and overturned, it is very difficult, if not impossible, to measure exactly the thickness of these formations. Dale, however, gives the

1. Hobbs, Note on the Geology of Southwestern New England, p. 175.

following approximations.

	Minimum	Maximum
Greylock schist	1500 feet	2200 feet
Bellowspipe limestone	600 "	700 "
Berkshire schist	1000 "	2000 "
Stockbridge limestone	1200 "	1400 "
Vermont formation	800 "	900 "
	5100 feet	7200 feet

Monument Mountain offers a good illustration of the frequency with which sediments change in this part of Massachusetts. Arenaceous, calcareous, and argillaceous sediments recur at relatively short intervals of time and space. A brief résumé of the formations as they occur here is as follows.

(1) Limestone and marble (1000-1400 feet), representing the Stockbridge limestone.

(2) Muscovite-(sericite-)chlorite schist (300 feet), representing the Berkshire schist.

(3) a. Muscovite-biotite schist, with porphyritic feldspars; b. A similar finer grained but calcareous rock; c. An impure limestone -- (500 feet), representing either the Stockbridge limestone, or the Berkshire schist, or the Bellowspipe limestone. This has not been definitely determined as yet.

(4) Quartzite (500-600 feet), representing either the Stockbridge limestone or the Bellowspipe limestone.[1]

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1. Dale, The Structure of Monument Mountain, pp. 558-559.

Mount Washington mass

The Mt. Washington series was determined by Hobbs to consist of four horizons.[1] Two of them are calcareous, and they alternate with two schist formations. To these Hobbs gave local names, but further study of the region showed definitely and conclusively that lithologically and structurally this series corresponds with the Greylock series 35 miles to the north,[2] and therefore the names of the latter horizons were substituted for the local names, as follows:

Mt. Washington Series		Mt. Greylock Series (Dale)
4. Everett schist	-	Greylock schist
3. Egremont limestone	-	Bellowspipe limestone
2. Riga schist	-	Berkshire schist
1. Canaan dolomite	-	Stockbridge limestone

Stockbridge Limestone. Here the rock is rich in magnesium and in some localities it is a true dolomite. It is characterized by the presence of salite and tremolite. Locally, its upper portions, near the schist, become graphitic.

Berkshire Schist. This is fairly uniform in character. Because of the abundance of feldspar it is really a gneiss, but it is more convenient to refer to it as a schist because it most resembles it in structure. It is porphyritic in character, containing oblong

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1. Hobbs, On the Geological Structure of the Mt. Washington Mass, pp. 725-726.
2. Hobbs, Note on the Geology of Southwestern New England, pp. 175-177.

and round grains of an acid plagioclase. It also has chlorite, garnets, staurolite, ottrelite, biotite, and tourmaline in many localities.

Bellowspipe Limestone. In the valley this is a white to gray crystalline limestone, quite pure except for small scales of colorless mica and grains of pyrite. On the summit plains it varies from a very micaceous limestone or calcareous mica schist to a graphite schist which is usually calcareous. It is impossible to measure its thickness accurately, but Hobbs estimates it to be from 100-800 feet.

Greylock Schist. It is difficult to distinguish this from the Berkshire schist, the most apparent difference between the two being the entire absence of macroscopic garnets and staurolites in the Greylock schist.

From his microscopic examinations of thin sections of the rocks of this area, Hobbs determined that they are all clastic rocks strongly metamorphosed by forces which operated on the region at several more or less distinct periods.[1]

The portion of the Mt. Washington mass in the State of Connecticut, of which Bear Mountain in Salisbury (Map C) is the highest point (2355 feet above sea level), has outcrops of the Vermont formation, the

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1. Hobbs, On the Geological Structure of the Mt. Washington Mass, pp. 726-735.

the Stockbridge limestone, and the Berkshire schist.[1]

Vermont Formation. In Connecticut this is called Poughquag quartzite or Cheshire quartzite. It is of two types, one of which is massive granular, composed largely of quartz and feldspar (microcline, orthoclase, and a small amount of plagioclase), and the other of which is schistose, in which a large amount of mica (usually biotite) is present. When it is exposed to the atmosphere for a long time this quartzite weathers to a dull brown color, due to hydrated iron oxide.

Stockbridge Limestone. Here it is a light gray to white marble of medium grain, usually calcitic but locally becoming dolomitic. It is characterized by the presence of imbedded metamorphosed minerals, the most noticeable of which is a white pyroxene (diopside) known to quarrymen as "Jason's teeth". Tremolite, phlogopite, sericite, pyrite, chalcopyrite, black calcite, and talc are some of the other minerals which occur in it. Because of its complicated structure its thickness can not be determined with accuracy.

Berkshire Schist. In this area this is usually a gray or greenish gray muscovite-biotite schist with rusty foliation planes, in places, especially toward the base of Mt. Washington, passing into a

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1. The following descriptions are taken from Gregory, The Crystalline Rocks, pp. 86-93, and Preliminary Geological Map of Connecticut, p. 33.

chlorite or graphite schist. It contains porphyritic minerals, among them being feldspar, garnet, staurolite, biotite, and tourmaline. This rock constitutes Bear Mountain (Map C), Indian Mountain (Map D), and a number of the smaller hills of the region. It always lies above and is conformable with the Stockbridge limestone. The transition between the two is gradual, constituting a zone of calcareous schist and micaceous limestone 10-25 feet thick, and grading into the limestone below and the schist above.

No fossils have yet been found in any of these rocks.[1]

Northern End

This portion of the Taconic area is an important one, for the principal formations of the region all meet within an area of a few square miles. However, it is a particularly complex region and although several geologists, including T. N. Dale,[2] C. E. Gordon,[3] and Arthur Keith[4], have given much study to it, the problems are not solved, and neither the stratigraphy nor the structure are completely understood as yet.

Berkshire Schist. The rocks of the main portion of the Taconic range and its outlying hills are

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1. Rice, The Geography of Connecticut, p. 23.
2. Dale, Geology of the North End of the Taconic Range.
3. Gordon, Studies in the Geology of Western Vermont.
4. Keith, Cambrian Succession of Northwestern Vermont.

prevailingly coarse schists, with some alteration into phyllites, quartzites, and conglomerates. Practically it has been found impossible to separate these and so the whole are termed Berkshire schist. It is not a homogeneous formation. It is difficult to distinguish some of its members from rocks found in the Green Mountain plateau on the east and the slate belt on the west. It is hard to define its boundaries also. Its age has been determined, but not conclusively, as Ordovician.[1]

Slate Belt. From the northern end of the Taconic region south to West Rupert (Map A), along the western slope of the mountains, is a belt of rocks called the "roofing slate belt". The entire belt is about 70 miles in length, and varies in breadth from eight to eleven miles at the north to two to three miles at the south, and extends into New York State in a broad band. There is no sharp boundary between the slates and the Berkshire schists. The description of these slates by T. N. Dale, quoted by C. E. Gordon in Studies in the Geology of Western Vermont,[2] is as follows.

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1. Dale, Geology of the North End of the Taconic Range, p. 188; Gordon, Studies in the Geology of Western Vermont, (3d Paper), pp. 222-223.
2. (1st Paper), p. 130.

Cambrian

a. Olive grit, more or less massive, sometimes with small quartzite beds. Has associated with it, in places, a bed of quartzite 12-55 feet thick.

b. Roofing slates, grayish green, purple, or mixed green and purple, alternating with beds of calcareous quartzite (5 feet) and limestone breccia up to 40 feet thick.

c. Dark gray grit, or sandstone, with shaly patches.

d. Black shales or slates with thin beds of limestone breccia.

e. Quartzite, usually with spots of limonite, and with some variations and sometimes associated with a quartz conglomerate.

Ordovician

a. Gray or black shales and thin-bedded limestones; possibly intermittent. ("Calciferous")

b. Black or gray shales and slates, sometimes banded from bedding. ("Hudson Shales")

c. Greenish or black, more or less quartzose, shales and slates, weathering white or whitish. ("Hudson White Beds")

d. Gray grit interbedded with black shales or slates. ("Hudson Grits")

e. Green or dull reddish or purplish phyllite with very thin beds of quartzite. ("Hudson Thin Quartzite")

f. Red and green roofing slate. ("Hudson Red and Green Slate")

It will be noted that Cambrian and Ordovician ages were assigned to these slates. This determination is due largely to Walcott's paleontological data corroborated by Dale's stratigraphical observations.[1]

It will also be noted that in this western portion of the Taconic region the Ordovician schists are in direct contact with the Cambrian and Ordovician slates. This involves the absence of the Stockbridge limestone along the western foot of the range in its northern portion, an unusual condition.[2]

Stockbridge Limestone. This has apparently a wide distribution, with, however, a great many interruptions over large areas, due in part at least to erosion.

The Taconic range finally terminates on the north in a central tongue of Cambrian slate and quartzite which is bordered on both the east and west by narrow strips of Ordovician schist and slate. On the south

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1. Dale, Geology of the North End of the Taconic Range, pp. 186-188.
2. Idem.

and east it is adjacent to a larger mass of Ordovician schist, two miles wide, which constitutes the northern end of the Taconic range proper. On the north and in several places on the sides the tongue is surrounded by Stockbridge limestone.[1]

Bird Mountain, which has been studied in some detail by Dale, consists of about 500 feet of grit and conglomerate interbedded with and underlain by muscovite-(sericite-)schist belonging to the Berkshire schist formation.[2]

Grit and Conglomerate. This is characterized by the chloritic green of the cement, by the presence of milky, bluish, or pinkish quartz pebbles an inch or so in diameter, and by the abundance of pebbles of a dense pale green rock. Pyrite is often found in the cement. All the rock is metamorphic in character. The interbedding with the schist is more or less irregular. The grit is probably of Ordovician age.

Berkshire Schist. The muscovite-(sericite-) schist varies in the several outcrops on the different sides of the mountain from a purplish schist containing sericite, quartz, and hematite, to a green schist containing sericite, quartz, and chlorite, but no

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1. Dale, Geology of the North End of the Taconic Range, p. 187.
2. Dale, A Study of Bird Mountain, pp. 15-23.

hematite. Almost all of the schist contains actinolite prisms, which produce a fine speckling.

Vermont-Berkshire Valley

The metamorphic dolomitic limestone which constitutes the floor of the valley throughout most of its extent is called the Stockbridge limestone, being so named because of its occurrence at Stockbridge, Massachusetts. It is a prominent formation along the eastern part of the United States, and is found in more or less parallel belts extending from Vermont to Georgia. It includes some of the most important building stones of the United States.[1] Because of its slight resistance to erosion it usually constitutes valley areas. Locally quartzites and schists are frequently found associated with it.

In Vermont dolomitic and calcareous variations occur in close proximity with each other. Since much marble is quarried from the formation there the name "marble formation" is generally given to it, although not all of the rock is a true marble. Besides extending along the main valley, this marble rock also extends into the Taconic range along the valleys of some of the streams.[2]

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1. Gregory, The Crystalline Rocks, pp. 87-88.
2. Gordon, Studies in the Geology of Western Vermont, (3d Paper), pp. 220-221.

Rising above the general level of the valley floor throughout its entire extent are numerous isolated ridges and hills of schist, graphically described by Dana as "islands in a sea". The schist of which they are composed belongs to the Berkshire schist formation.[1]

Rensselaer Plateau

This tableland, which stretches from the Taconic Mountains to the Hudson River, is composed of Stockbridge limestone, Berkshire schist, and Rensselaer grit.[2]

Stockbridge Limestone. The lower part, which is of Cambrian age, consists of alternating beds of limestone, greenish, reddish, or purplish shale, and massive, sometimes greenish, quartzite. The upper part, often called Beekmantown shale, is Ordovician in age. It is a greenish or grayish shale with small beds of finely banded quartzite. Estimates as to the thickness of the formation vary from 336 to 1275 feet.

Berkshire Schist. In this locality it is

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1. Dale, On the Structure and Age of the Stockbridge Limestone, passim; On the Structure of the Ridge between the Taconic and Green Mountain Ranges, passim; Hobbs, The Geological Structure of the Housatonic Valley, passim.
2. Dale, The Rensselaer Grit Plateau, pp. 328-329; Geology of the Hudson Valley, passim.

generally called Hudson shale or Hudson schist. It is Upper Ordovician in age, and is connected stratigraphically with the slate and schist along the Hudson River. It has been stated[1] that the shale, slate, and schist are phases of the same rock. Where it is unmetamorphosed it is shale; where slightly metamorphosed it is slate; and where metamorphism has been accomplished to a great degree it is schist. The rock is chiefly a black, gray, reddish, greenish, or purplish shale irregularly interbedded with grit, limestone, limestone conglomerate, or quartzite beds. Its estimated thickness is from 1200 to 2500 feet.

Rensselaer Grit. This formation is a dark green metamorphosed conglomerate, crystalline and granular, interbedded with reddish, greenish, and purplish shale or slate. It contains pebbles of quartzite, marble, shale, slate, grit, and phyllite of Cambrian and Ordovician age, and some pebbles of gneiss and granite of Pre-Cambrian age. Its thickness can not be accurately measured because of the uncertainty of the number of folds in the region, but it is estimated at about 1400 feet. Dale puts this formation in Lower Silurian time, but Barrell, because of its color and arenaceous character, assigns it to the Middle Devonian.[2]

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1. Gregory, The Crystalline Rocks, p. 93.
2. Barrell, Upper Devonian Delta, pp. 448-449.

STRUCTURE

General features

In 1884 Dana described the synclinal structure of the Taconic Mountains.[1] The later work of Dale in various parts of the Taconic region (see Bibliography) and of numerous other geologists, particularly those of the United States Geological Survey, proved Dana was right and established the fact in great detail. Dale summarized the general structural characteristics[2] as a succession of major and minor folds corresponding approximately to the trend of the range. The term used now is synclinorial, denoting a succession of synclines, rather than synclinal, which was used by Dana and the earlier geologists. This synclinorial character has been established not only for the main Taconic range but also for the spurs and outliers, the Vermont-Berkshire Valley, and the Rensselaer Plateau. The folds vary from close to open and from erect to inclined.

Raphael Pumpelly, who directed the work of the geologists of the United States Geological Survey in the vicinity of Mt. Greylock, stated that in looking for the key to the structure of the range he "sought a region where the western edge should

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1. Dana, On the Southward Ending of a Great Synclinal.
2. Dale, Taconic Physiography, p. 26.

present, instead of a straight line, as many bay-like curves as possible and where the structure of the ridge itself should show folds with pitching axes. I hoped in such a region to eliminate the difficulties introduced by possible faults, as well as the temptation to infer their existence."[1]

This absence of faulting is the fundamental assumption of Pumpelly, Dale, and their fellow geologists in their work in this region, and to this assumption W. H. Hobbs takes very great exception. In his paper The Geological Structure of the Southwestern New England Region he gives a preliminary notice of a larger work which is to appear, in which he will attempt to prove "that no adequate explanation can be offered for the present attitudes of the rocks within that belt which fails to take account of a deformation by normal faulting as well as by folding."[2] He declares that deformation by folding alone has proven entirely inadequate. Furthermore, his study of the Newark belt of Connecticut showed that it was deformed by a complex system of parallel and intersecting faults all near the vertical, and he believes that these faults must necessarily extend beyond Connecticut and into the Taconic

1. Pumpelly, Geology of the Green Mountains, pp. 7-8.
2. P. 442.

area. These faults he describes as of Post-Newark (Triassic) age and as superimposed upon older structures which are due largely to folding.

It must be remembered, however, that Hobbs is extremely partial to faulting as an explanation of geological structures and that he emphasizes it in every connection possible. Moreover, in the absence of his promised paper, we can but present here the conclusions reached by Dale and, in the case of Mt. Washington and the Housatonic Valley, the earlier opinions of Hobbs.

In general, one word will describe the structure of the Taconic region: complex.

Mount Greylock mass

This mountain is one of the best fields for the study of the relations of the Taconic rocks to each other. Once more the classic work of T. N. Dale will serve as my source for this region.[1] All the localities referred to in this section, unless otherwise noted, will be found on Map E.

To work out the geologic structure of Mt. Greylock one must understand the relations of cleavage and stratification, and the relation of these to the folds. This is no small task. The marks of stratification are often subject to local changes. Sometimes the cleavage foliation agrees with the stratification foliation in both strike and dip; sometimes it differs in respect to one, and at others in respect to both. It was a large task which Dale and his assistants faced.

It was determined that cleavage phenomena affect both the limestone and the schist, and that both stratification and cleavage foliations may be equally or unequally dominant or microscopic. The cleavage dip is almost universally easterly here. The pitch varies from 5° to 45° but generally it is not over 30°. In one or two instances only it is over 45°. The direction of the pitch in the northern

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1. Dale, <u>Mt. Greylock: Its Areal and Structural Geology</u>, pp. 136-179.

part of the central ridge is southerly, while in the southern portion it is northerly.

From the data he collected Dale laid down the following structural principles as applicable primarily to the study of the metamorphic rocks of Mt. Greylock and then to a large part of the Taconic region.[1]

1. The lamination in schist or limestone may be either stratification foliation or cleavage foliation, or possibly a combination of both. False bedding occurs in limestone also. Therefore the conformability of two adjacent rocks is shown only by the conformability of the stratification foliation of both.

2. Stratification foliation is indicated by: (a) the course of minute plications visible to the naked eye, (b) the course of the microscopic plications, and (c) the general course of the quartz laminae whenever they can be clearly distinguished from those which lie in the cleavage planes.

3. Cleavage foliation may consist of: (a) planes produced by or coincident with the faulted limbs of the minute plications, (b) planes of fracture resembling joints on a very minute scale, with or without faulting of the plications, and (c) a cleavage approaching "slaty cleavage", in which the

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1. <u>Ibid</u>., p. 158.

axis of all the particles have assumed either the direction of the cleavage or one forming a very acute angle to it, and where stratification foliation is no longer visible. These forms may all occur in close proximity.

4. A secondary cleavage, resembling a minute jointing, occurs in scattered localities, and, although not yet very satisfactorily observed on Greylock, original cleavage foliation may become plicated by secondary pressure.

5. The degree and direction of the pitch of a fold are often indicated by those of the axes of the minor plications on its sides.

6. The strike of the stratification foliation and cleavage foliation often differ in the same rock, and are then regarded as indicating a pitching fold.

7. Such a correspondence exists between the stratification and cleavage foliations of the great folds and those of the minute plications that a very small specimen, properly oriented, gives, in many cases, the key to the structure over a large portion of the side of a fold.

On these principles Dale constructed twelve complete and three partial transverse sections across the Mt. Greylock mass.[1] The first section he took

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1. Ibid., Plates XVIII to XXII.

across the northern end at North Adams and the last across the southern end, between Cheshire and Berkshire villages. The others are spaced more or less regularly at intervals between these. Of these I have reproduced on pages 54 and 55 the four more important ones: Section G, from the Hoosic River at Renfrew Mills (South Adams) across Ragged Mountain, the central ridge, Mt. Prospect, and the northern end of Deer Hill; Section H, across the summit of Greylock; Section I, from the Hoosic River above Maple Grove Station (South Adams), across the central ridge, Stony Ledge, the southern end of Deer Hill, to the Green River; and Section K, from a little north of Cheshire Harbor, across Bassett Brook, Saddle Ball, Mitchell Brook, East Branch of Green River, and Green River. (See Map E for section lines.)

A study of these transverse sections will show the structure of the mountain far more clearly than words can represent it. It will be seen that the ridge consists of a series of more or less open or compressed synclines and anticlines.

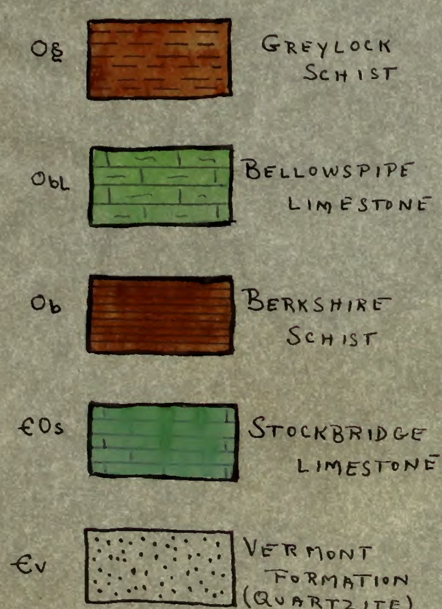
The rest of Dale's sections, which I have not reproduced here, show that going south from North Adams the synclines and anticlines increase in number and altitude until they reach a point a mile and a half south of Mr. Greylock summit, where they then

across the northern end at North Adams and the last across the southern end, between Cheshire and Berkshire villages. The others are spaced more or less regularly at intervals between these. Of these I have reproduced on pages 54 and 55 the four more important ones: Section G, from the Hoosic River at Renfrew Mills (South Adams) across Ragged Mountain, the central ridge, Mt. Prospect, and the northern end of Deer Hill; Section H, across the summit of Greylock; Section I, from the Hoosic River above Maple Grove Station (South Adams), across the central ridge, Stony Ledge, the southern end of Deer Hill, to the Green River; and Section K, from a little north of Cheshire Harbor, across Bassett Brook, Saddle Ball, Mitchell Brook, West Branch of Green River, and Green River. (See Map 3 for section lines.)

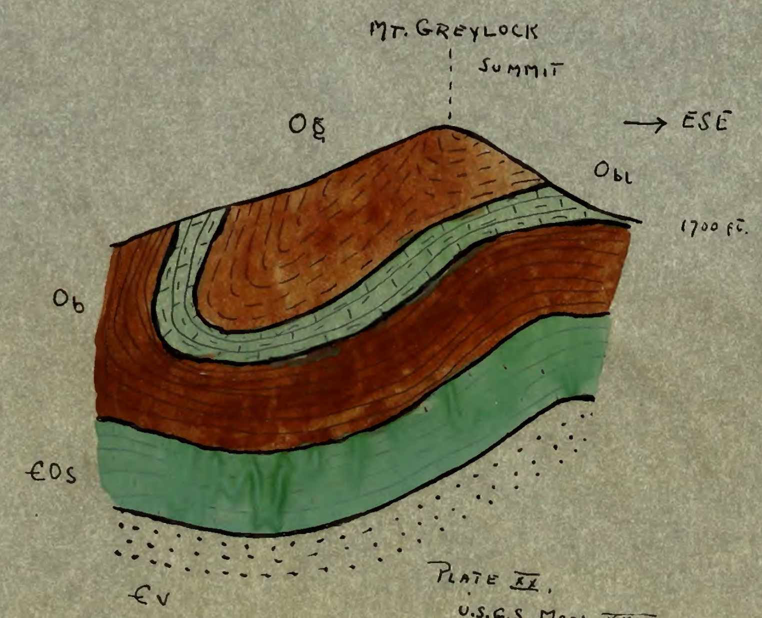
A study of these transverse sections will show the structure of the mountain far more clearly than words can represent it. It will be seen that the ridge consists of a series of more or less open or compressed synclines and anticlines.

The rest of Dale's sections, which I have not reproduced here, show that going south from North Adams the synclines and anticlines increase in number and altitude until they reach a point a mile and a half south of Mt. Greylock summit, where they then

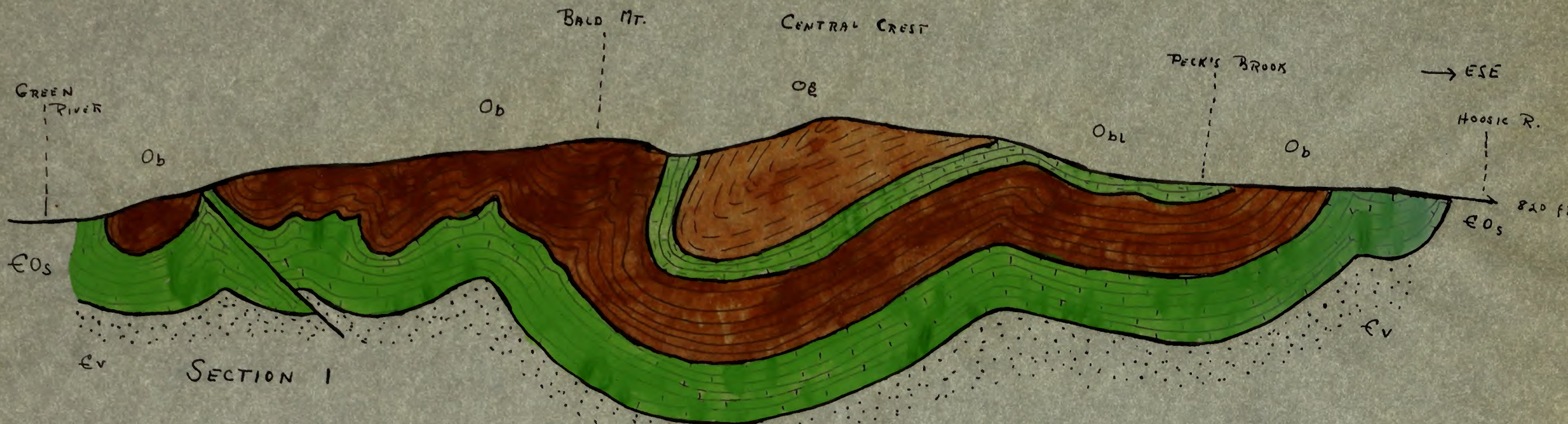
Section G



Section H

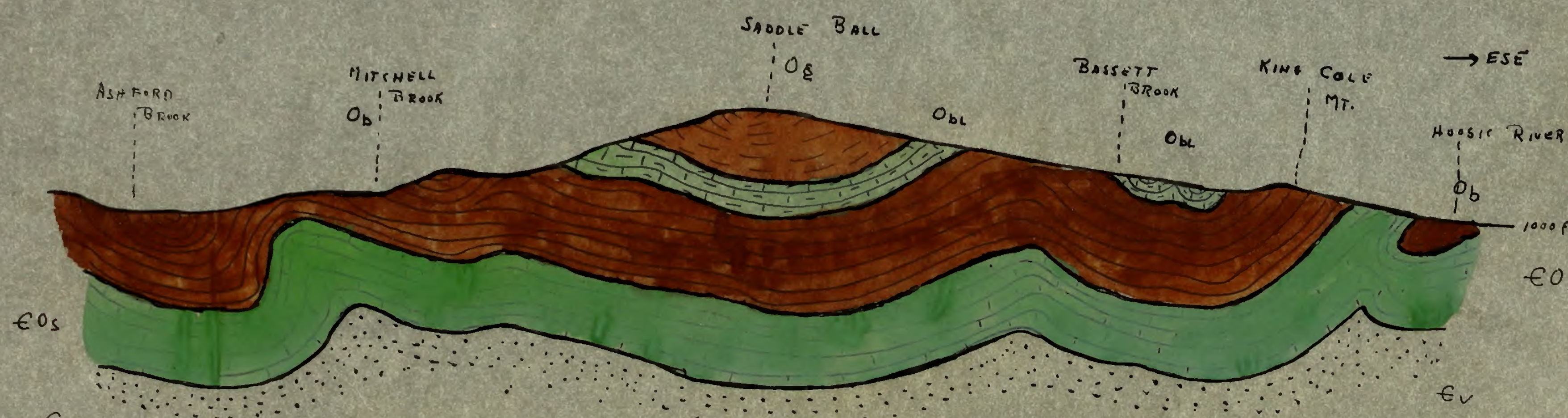



Section H
Section G
Vermont Formation (Quartzite)
Stockbridge Limestone
Berkshire Schist
Bellowspipe Limestone
Greylock Schist
Mt Greylock Summit
Mt Prospect
Central Crest
Bellowspipe
Ragged Mt
Hopper Brook
Deer Hill (North End)
Hoosic
ESE



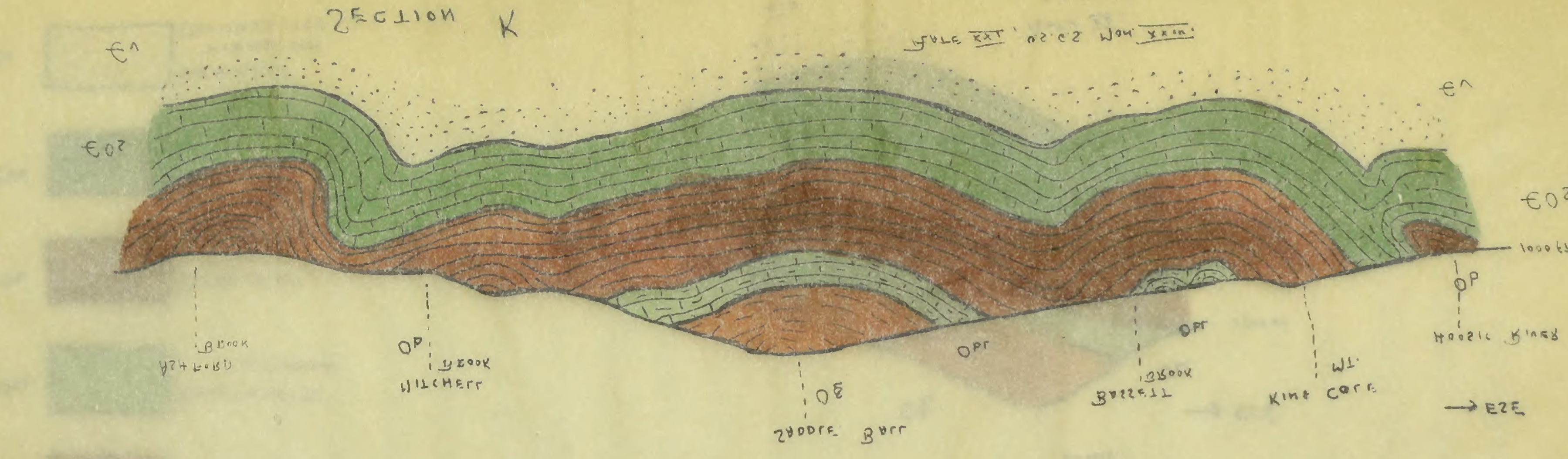
Section I

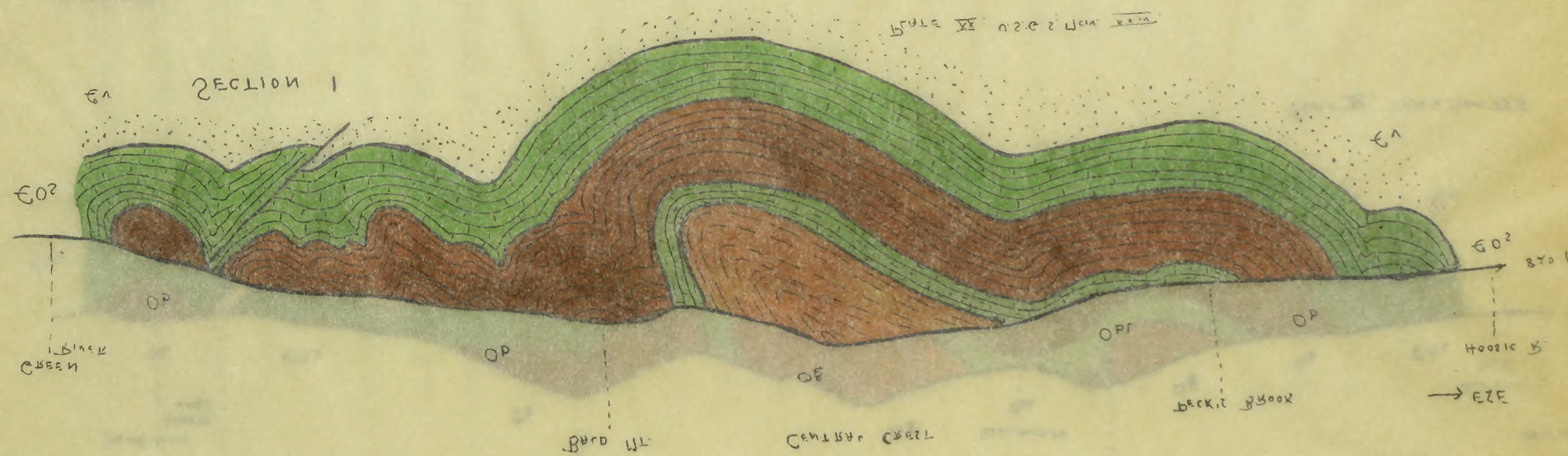
Plate XX, U.S.G.S. Mon. XXIII.



Section K

Plate XXI, U.S.G.S. Mon. XXIII.


SECTION K
PLATE XXI, U.S.G.S. MON. XXIII
Є^
Є0²
1000 ft
OP
OPL
OB
ASHFORD BROOK
MITCHELL BROOK
SADDLE BALL
BASSETT BROOK
MT. KING COLE
HOOSIC RIVER
→ ESE


SECTION I
PLATE XX, U.S.G.S. MON. XXIII
Є^
Є0²
OP
OPL
OB
GREEN RIVER
BALD MT.
CENTRAL CREST
PECK'S BROOK
HOOSIC R.
→ ESE

begin to widen out and diminish in number and height until they finally pass into a few broad undulations west of Cheshire. Between Cheshire and the villages of Lanesboro and Berkshire the folds become sharper and more compressed.

I have also reproduced, on page 57, Dale's longitudinal section Q.[1] This follows the axis of the central syncline for fourteen and a half miles, starting at the foot of Clarksburg Mountain. The section shows a deep trough, with a steep southerly pitch at the north end, with its center at cross section I, in the saddle between Mt. Greylock and Saddle Ball.

Mt. Greylock, then, with its subordinate ridges, is a synclinorium consisting, in its broadest portion, of ten or eleven synclines alternating with as many anticlines. However, when the sections are carried down, it is found that these synclines resolve themselves into two great ones with several smaller, lateral ones. The larger of the two forms the central ridge of the mass, while the smaller one, on the east, forms Ragged Mountain and its neighboring line of hills. The hollow between these two peaks, called the Bellowspipe, is the result of the anticline between the synclines. The anticline west of the central syncline is a little west of the north

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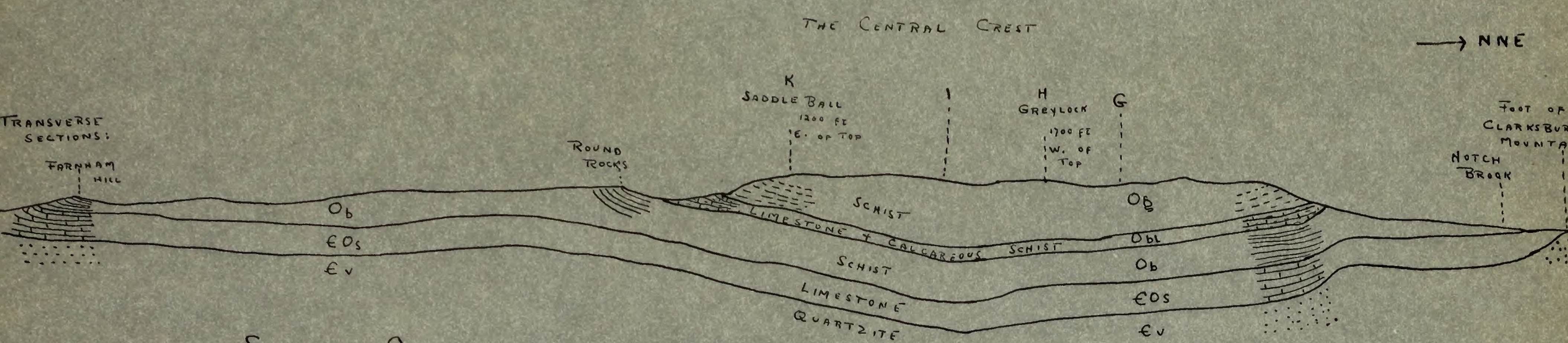
1. *Ibid.*, Plate XXIII.



SECTION Q

PLATE XXIII, U.S.G.S. MON. XXIII.

and south part of the Hopper. The folds to the east or west of the two main synclines are more or less open, and have their axial planes vertical or else inclined east or west. The longitudinal section Q shows that the deepest part of the synclinorium is between Mt. Greylock and Saddle Ball (Section I). The cleavage foliation across these folds dips almost universally east.

Monument Mountain, which lies in line with the Greylock synclinorium but about thirty miles to the south-southeast, is itself a small synclinorium, consisting of two major synclines with intervening minor folds. (Figure 1, page 59.[1]) Dale explains the relations of the limestone and the schist on the eastern part of the mass by supposing a fault, as indicated in the figure, but adds that it may possibly be due to a sharp compressed syncline overturned to the west.[2]

As mentioned before, East and Potter Mountains (Map B) form a connecting link between the Mt. Greylock mass and the Taconic range proper. A portion of Section L shown in Dale's Mt. Greylock, above referred to, reveals the open syncline which forms East Mountain. (Figure 2, page 59.[3])

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1. Dale, The Structure of Monument Mountain, p. 559, Plate LXXII, figure E.
2. Ibid., p. 565.
3. Plate XXI.

Plate LXXII, Fig. E,
U.S.G.S. 14" An. Rpt.

Figure 1.
Monument Mountain

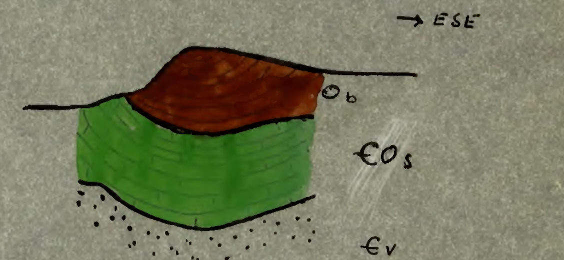
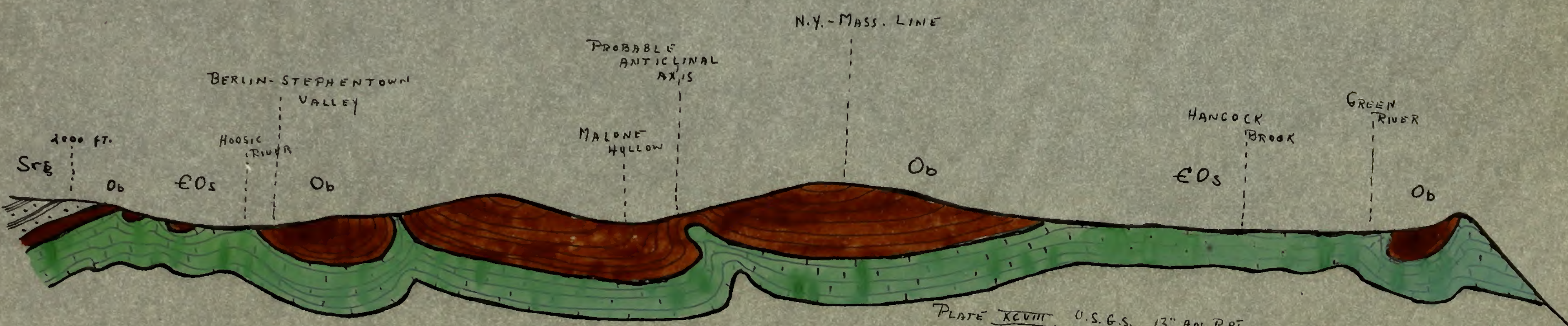


Plate XVI, U.S.G.S. Mon. XXIV.
Part of Section L.

Figure 2.
East Mountain



Srg - Silurian
Rensselaer Grit

Figure 3. Taconic Range

Figure 3. Taconic Range

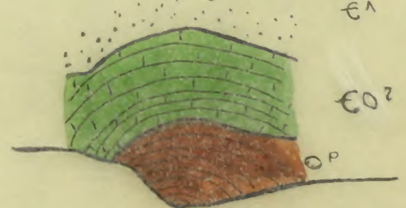
Plate XCVIII, U.S.G.S. 13th An. Rpt.

Figure 1. Monument Mountain

Plate LXXII, Fig. 6. U.S.G.S. 14th An. Rpt.

Figure 2. East Mountain

Part of Section L. Plate XII, U.S.G.S. Mon. XXIII.



No cross section of Potter Mountain has yet been made, but Dale's work in that locality would indicate that the East Mountain synclinal structure continues through Potter Mountain and also includes one or more additional synclines, possibly compressed and overturned.[1]

The principal structural features of the rest of the Taconic Mountains at this point are shown in Figure 3 on page 59.[2] This section extends from Deer Hill, at the west foot of Mt. Greylock, eighteen miles to Poestenkill, New York. This section has not been drawn with the exactitude with which the Mt. Greylock sections were made, for a great deal of additional study will have to be made in the region before that can be accomplished. However, the decrease in the number of closed and overturned folds west of Mt. Greylock has been ascertained and shown. Dale's observations have led to the conclusion that two anticlinal axes run through the middle of the Taconic mass, and these are shown. There is also shown the fact that the ridges of the Taconics are the result of more or less complex schist synclines and the valleys, of limestone anticlines. In other words, the synclinorial structure of the mountain range is known and shown.

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1. Dale, The Rensselaer Grit Plateau, pp. 316-317.
2. Ibid., pp. 316-317, Plate XCVIII.

Mount Washington mass

It is to Hobbs that we must go for sections showing the structure of Mt. Washington[1] (Map C). I have reproduced four of his cross sections on page 62. These sections show that the southern portion of the mountain is largely an anticline of schist with minor symmetrical folds. Going northward, the western syncline grows wider and deeper, while the eastern limb of the anticline is narrowed, compressed, and finally overturned. The central portion of the mountain thus has two synclines, which are deeply corrugated, which form the eastern and western schist ridges. Between these synclines lies an anticline, also deeply corrugated, which forms the summit plain. Proceeding further north, the folds become narrower and deeper, and are reversed. This narrowing of the folds explains the contraction of the mountain at its northern end.

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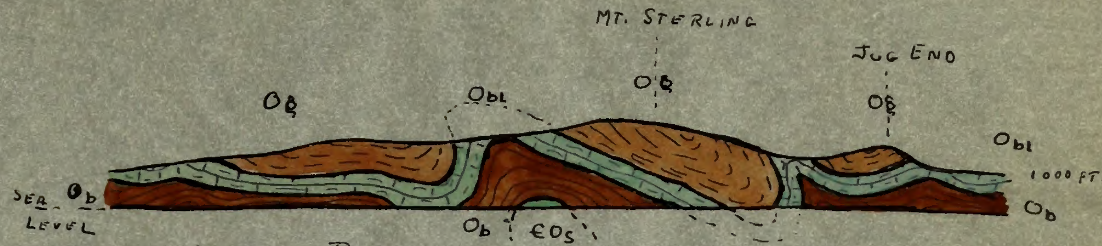
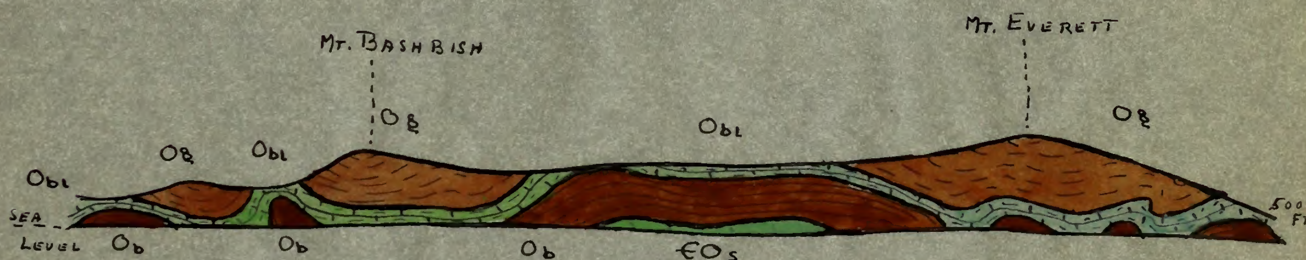
1. Hobbs, On the Geological Structure of the Mt. Washington Mass, p. 732, Plate IV.

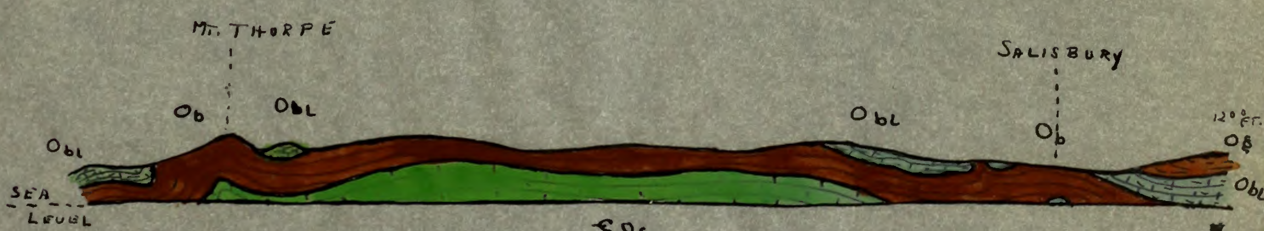


Section B.



Section D.

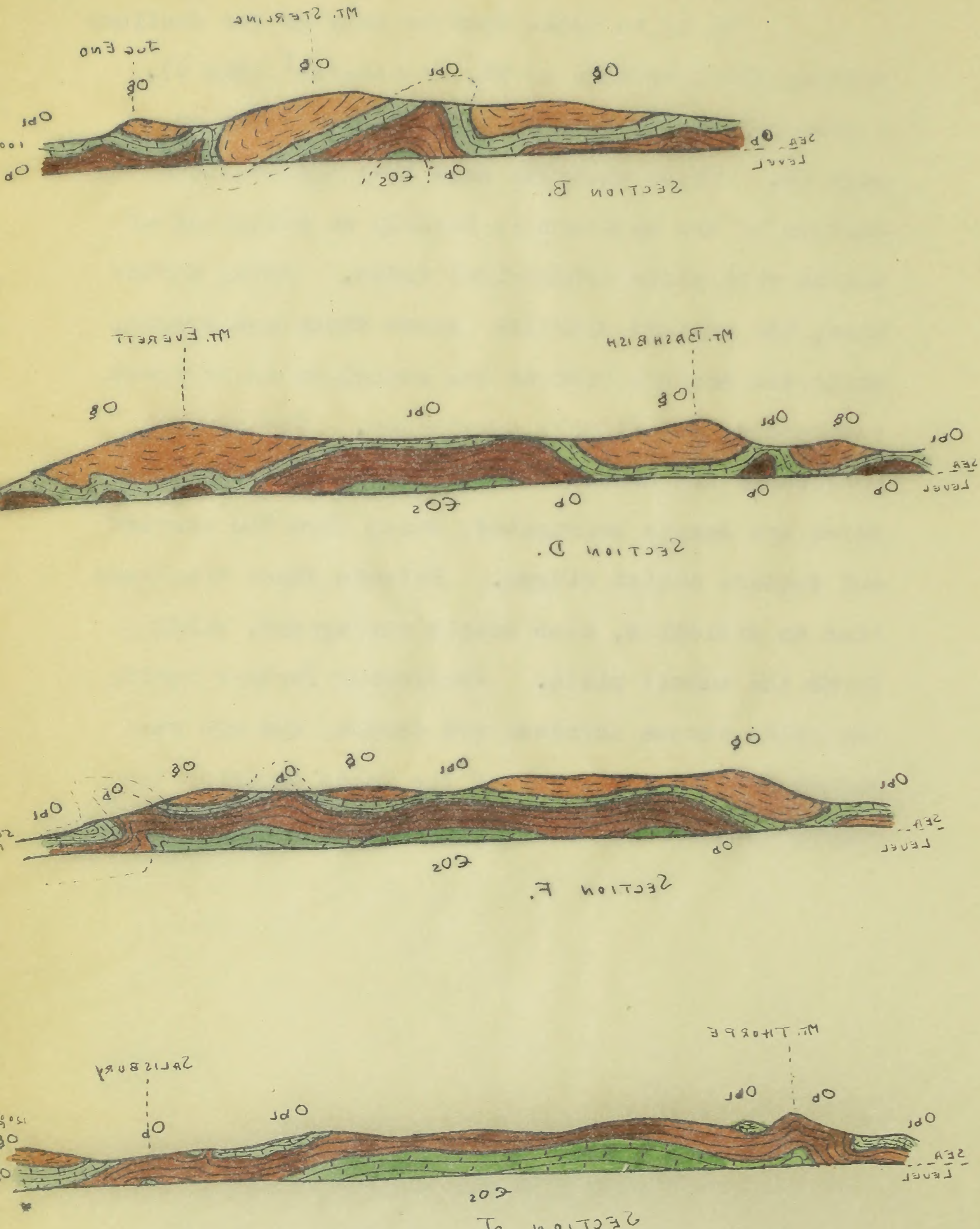
Section F.



Section J.

Sections through Mt. Washington

Plate IV, J. G. 1.



SECTIONS THROUGH MT. WASHINGTON

Northern End

Little is known of the details of the structure of the northern end of the Taconic Mountains, with the exception of Bird Mountain. Dale has made some study of this portion of the range.[1] In general, the structure of this region is important because of the unusual absence of the Stockbridge limestone on the western side so that the Ordovician Berkshire schist is in direct contact with the Lower Cambrian slate. This feature was pointed out in the section on the stratigraphy of the northern end. The prevalent strike of the Cambrian area of the northern portion is about northeast, while that of the Ordovician rocks is N 15-25° W. There is a definite unconformity between the Cambrian and the Ordovician strata here, an unconformity probably produced by a cycle of uplift, erosion, submergence, and deposition, rather than by a fault plane. No sections are yet available for this region as a whole.

The structure of Bird Mountain is known in greater detail, but unlike the case of Mt. Greylock, Bird Mountain should not be taken as the type of the whole northern region, for it is more than probable that here each peak has its own more or less special structure.[2]

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1. Dale, Geology of the North End of the Taconic Range; The Ordovician Outlier at Hyde Manor.
2. Perkins, The Physiography of Vermont, pp. 10-11.

Northern End

Little is known of the details of the structure of the northern end of the Oquirrh Mountains, with the exception of Bird Mountain.[1] [illegible] has made some study of this portion of the range. In general, the structure of this region is important because of the unusual absence of the [illegible] limestone on the [illegible] side so that the [illegible] [illegible] which is in direct contact with the [illegible] [illegible]. This feature was [illegible] out by [illegible] on the [illegible] [illegible] of the [illegible]. The prevalent strike of the Cambrian area of the northern portion is about northeast, while that of the [illegible] rocks is [illegible]. There is a definite unconformity between the Cambrian and the [illegible] strata here, an unconformity probably produced by a cycle of uplift, [illegible], [illegible], and [illegible]. [illegible] [illegible] [illegible] [illegible] for this region as a whole.

The structure of Bird Mountain is known in greater detail, but unlike the case of Mt. [illegible], Bird Mountain should not be taken as the type of the whole northern region, for it is more than probable that [illegible] [illegible] others.

1. [illegible], Geology of the North End of the [illegible] Range; [illegible]
2. [illegible], The [illegible] of [illegible], pp. 10-11.

As shown by Figure 1 on page 65,[1] Bird Mountain is an open syncline, the axis of which runs along the western half of the mass. The syncline is crossed by several sets of joints which dip steeply to the east. Towards the south the mass grows a little more complex, developing into two synclines rather than one. There are numerous indications that the mountain was formerly much more extensive than at present and has been greatly reduced by erosion.

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1. Dale, A Study of Bird Mountain, p. 16, Plate I.

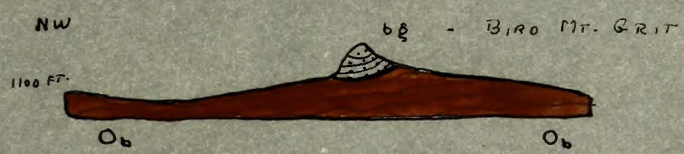

PLATE I
U.S.G.S. 20" AN. RPT.

FIGURE 1.

BIRD MOUNTAIN

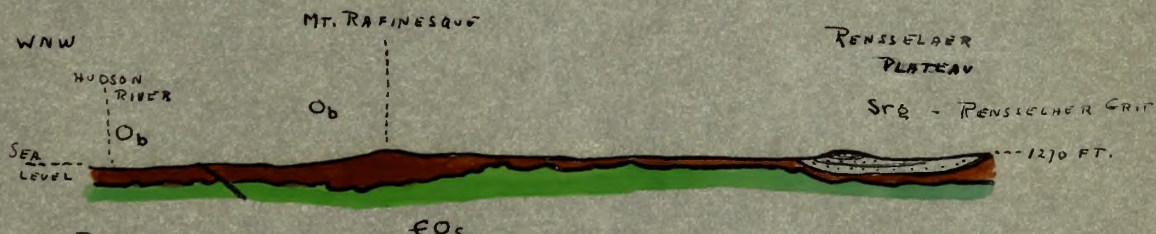

PLATE III, A,
U.S.G.S. BULL. 242.

FIGURE 2.

RENSSELAER PLATEAU

SECTION FROM NEAR QUACKENKILL IN GRAFTON TO THE HUDSON 2 MILES NORTH OF LANSINGBURG.

Figure 1.

Plate I
U.S.G.S. 20th An. Rpt.

Bird Mountain

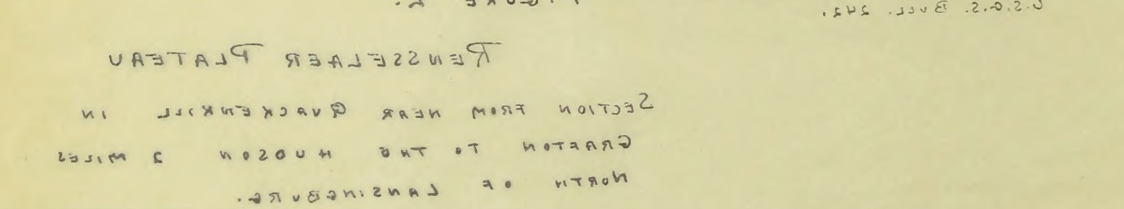

Figure 2.

Plate III, A,
U.S.G.S. Bull. 242.

Rensselaer Plateau

Section from near Quackenkill in
Grafton to the Hudson 2 miles
North of Lansingburg.

Vermont-Berkshire Valley.

Most of the many ridges which dot the valley area are anticlines of schist, although some are synclines. In the Housatonic portion of the valley these schist ridges seem to be arranged in four belts extending east and west, each about two miles wide, corresponding to the crests of a series of east-west folds. Going toward the north these four belts are subdivided by a smaller series of folds about half a mile in width. Along the eastern border of the schist ridges is a reversed fault. Its course nearly coincides with the course of the Housatonic River (Map C) for quite a distance. This fault is called the Housatonic fault. The northern part of it has something of the character of an overthrust fault.[1]

Gordon explains the whole Vermont Valley as a great downthrow region between the Green Mountain Plateau on the east and the Taconic range on the west.[2]

No structure sections of this valley region are available.

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1. Hobbs, <u>The Geological Structure of the Housatonic Valley</u>, p. 801.
2. Gordon, <u>Studies in Geology of Western Vermont</u>, (3d Paper), pp. 257-259.

Rensselaer Plateau

The general structure of this plateau, as determined by Dale[1], is, like the Taconic region as a whole, that of a synclinorium, with a well defined syncline along its eastern side, a compound syncline along its western side, and one or more folds between them. This synclinorium is from six to nine miles wide and about twenty miles in length. Figure 2 on page 65 shows this synclinorial structure, although not in very great detail.[2]

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1. Dale, The Rensselaer Grit Plateau, pp. 325-327.
2. Dale, Geology of the Hudson Valley, p. 44, part of section A of Plate III.

Metamorphism[1]

The Taconic region, like all of New England, is essentially a province of metamorphic rocks. A complete understanding of these rocks requires such a chemical and mineralogical understanding of the rocks as they exist and such a knowledge of the forces which are at work within the interior of the earth as the data at hand and the methods thus far developed are not able to furnish. Some of the most widespread formations still present unsolved problems.

There are all degrees of metamorphism. As introduced by Lyell, the term applies only to a profound change from the original condition. As often used today, it includes slight alteration, as in the case of a clay hardened by contact with heated rock. The common conception of metamorphism, however, is of a far-reaching change.

Usually the heat and pressure which have effected metamorphism have also destroyed all traces of former life, so that it is often difficult, if not impossible, to tell the exact age of metamorphic rocks. This is true in the Taconic region to quite an extent.

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1. The material for this section was taken from Gregory, The Crystalline Rocks, pp. 41-70, and Martin, James R., Lecture Notes in Petrology and Advanced Geology.

There are two types of metamorphism, contact, which is due to local developments, and regional, which is connected with orogenic movements and which affects rock deeply and on a large scale. The metamorphism in the Taconic area was of the latter type and took place during the period of orogeny which affected the region in Paleozoic time. As regional metamorphism always occurs at great depth within the crust of the earth, and as these metamorphic rocks are now exposed on the face of the earth, the vast amount of erosion that has taken place can readily be realized.

The principal metamorphic rocks are slate, schist, marble, quartzite, and gneiss. As only the first three of these appear in any great amount in the Taconic region, I shall limit myself almost exclusively to a consideration of these three rocks.

Slate. When shale is metamorphosed a definite series of rocks results, according to the amount of metamorphism which affects it. Slate is the first of the series. The feldspar of the shale is altered into mica and quartz, but the particles of these minerals are so fine that they can not be seen by the unaided eye. The compression exerted on the rock during metamorphism is so great that it forces all of the flat mica particles to lie

parallel to each other, and it is this perfect parallelism which gives to the slate its conspicuous characteristic of cleavage. Impurities in the original shale result in the formation of other minerals, such as pyrite, in the slate.

It is only occasionally that there have been produced slates of sufficiently good quality to have commercial value. The New York-Vermont slate region, within the Taconic area, is one of the few good localities of the United States.

Further metamorphism of slate gives phyllite, and extreme metamorphism gives schist.

Schist. Here the flakes of mica are much larger and are readily visible to the naked eye. The quartz grains, although they are large, are inconspicuous. The term "schist" indicates structure, not composition. The name of the mineral which is most abundant or which gives it its color is usually added to denote the specific kind of schist, such as hornblende schist, chlorite schist, etc. Mica schist is, however, the most common kind of schist. It constitutes the bed rock of most of New England, and it is the "mountain rock" of the Taconic region. Schists are commonly developed from shale, but they may also come from sandstone, conglomerate, and from fine-grained igneous rock. Schist breaks readily,

and usually with a wavy surface. It is too soft to be of any practical use.

The original rocks from which the schists come usually have impurities, and it is because of these that schists usually contain abundant minerals other than their main constituents. Garnet, staurolite, chlorite, talc, fibrolite, and cyanite are some of the common minerals thus found.

Marble. This term is used by stone-cutters to denote any rock which takes a high polish, but geologists use it only to indicate metamorphosed limestone. Metamorphism takes place by recrystallization. When pure calcite limestone is metamorphosed, pure white marble results. When the limestone is impure, the impurities alter during metamorphism. They segregate and develop into the minerals which commonly occur in marble, -- garnet, pyrite, pyroxene, actinolite, tremolite, and so on. Sometimes the impurities give a cloudy effect, or color the marble. For instance, chlorite and serpentine give a greenish tinge to marble, and graphite a blackish. There is little difference between a calcite and a dolomite marble, except in chemical composition.

Marble is the most attractive rock, and is much used for sculpturing and decoration, as well as for building purposes.

Quartzite. This is the hardest and most compact of our rocks. When sandstone is metamorphosed there is a partial fusion of the quartz grains, and recrystallization occurs. Only a physical change takes place, for quartzite consists of quartz as well as sandstone does. The rock is massive and resists erosion more than any other rock. For that reason it tends to stand in relief where it occurs with other less resistant rocks. When the quartzite is pure it is easy to recognize, but when impure it is very indefinite-looking. Only small outcrops of quartzite are found in the Taconic region.

Gneiss. The essential characteristics of gneiss are the coarse banded structure and the presence of feldspar. Gneisses may result from the metamorphism of sedimentary rock, but more commonly they come from igneous rocks. No gneisses occur within the Taconic area to any important extent.

Dale noted[1] that there is a decrease in the amount of metamorphism in the Taconic region on going west from the Vermont-Berkshire Valley. For instance, the Stockbridge limestone is more crystalline east of Mt. Greylock than in any of the valleys to the west of that mountain, and the schists of the Taconic

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1. Dale, The Rensselaer Grit Plateau, pp. 334-335.

range proper pass into phyllites and then into slates as one follows them westward. Dale also observed that the secondary albite which he found to be abundant in the Berkshire schist of Mt. Greylock occurs only occasionally on East Mountain, rarely on the western part of the Taconic range, and not at all on the Rensselaer Plateau.

HISTORICAL DEVELOPMENT

Pre-Cambrian through Ordovician

The Taconic Mountains constitute the oldest land area of North America outside of the Canadian Shield. Their history, then, is a long one, and it begins with Archaean time. The very early part, however, up to Cambrian time, may be passed over rather briefly.

The continental area of North America and the two deep seas, Atlantic and Pacific Oceans, have retained their relative positions since the beginning of Algonkian time[1], and the continent has been in practically full development as land since the close of Algonkian time[2]. This continental surface may be divided into four fundamental divisions[3]: (1) the eastern border region, (2) the Appalachian region, which includes the Taconic Mountain area, (3) the interior continental basin, and (4) the Pacific border region west of the Rocky Mountains. The Appalachian and Rocky Mountain chains have been boundaries since the beginning of Paleozoic time. These axial lines originated, however, in Archaean time and their elevation marked the birth of the Appalachian and

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1. Walcott, <u>North American Continent during Cambrian Time</u>, p. 563.
2. Ulrich and Schuchert, <u>Paleozoic Seas and Barriers</u>, p. 659.
3. Dana, <u>Areas of Continental Progress</u>, p. 36.

Rocky Mountain chains. For this reason Dana calls each the Archaean protaxis of the chain. The Appalachian protaxis extends along the Taconic and Green Mountain region as an interrupted range, and then continues southwestward to Georgia as a series of ridges. The protaxis, although not now the highest part of the chain, is the oldest part.

To the east of the Appalachian protaxis there extended three Archaean ranges, and between them there were three troughs. During Paleozoic time "rock-making" went on chiefly within these troughs, with some few exceptions. Because of the great thickness of the rock formations there laid down, it has been concluded that the troughs were profoundly subsiding areas.

One such long trough, evidently a synclinorium within an Algonkian continent, existed during Lower Cambrian time from Alabama northeastward to Labrador, including within it the Taconic area. The sea which filled it carried down rock material from the land mass to the east and deposited it on the floor of the trough to start the formation of the great sheet of Cambrian rocks which are now the chief basal deposits of the region. These detrital deposits were made over the shallow areas, while further offshore to the west calcareous material

was accumulating for the formation of limestone.

At the close of the Lower Cambrian the whole region was slightly elevated, and a fold appeared in the eastern part of the former trough. The sea was thus confined to the western half.[1] This slight crustal movement folded the Lower Cambrian rock formation at the northern end of the Taconic range and raised it above sea level, forming it into several islands in the sea. Most of the Taconic area, however, still remained below sea level.

The absence of Middle Cambrian strata in the Taconic region may be accounted for, perhaps, by this post-Lower Cambrian movement and uplift, which made the region temporarily a land surface.

Upper Cambrian time brought a new sea, which soon covered parts of the Appalachian trough. This sea allowed the accumulation of great beds of limestone, chiefly a dolomite. The thickness of the limestone deposits would indicate that the shores of the sea were remote and that the water was very deep. This depth of the sea may explain the paucity of animal remains found in this limestone.[2]

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1. Ulrich and Schuchert, Paleozoic Seas and Barriers, pp. 635-637.
2. Dale, The Ordovician Outlier, p. 524; Geology of the Hudson Valley, p. 49.

It is only in regions where the Upper Cambrian deposits are decidedly arenaceous, as in New York State, that there is a marked distinction between them and succeeding strata of Lower Ordovician age. In most of the Taconic area the deposits of both times are limestones, and thus it appears that in that region sedimentation, and probably subsidence, continued from the beginning of Upper Cambrian to the end of Lower Ordovician with little interruption, if any at all. Thus the Stockbridge limestone, so prevalent in the Taconic region, is a continuous formation of Upper Cambrian and Lower Ordovician age.

At the close of the Lower Ordovician a second crustal movement took place.[1] The fold of Lower Cambrian time was reëlevated and accentuated, and in addition a second fold emerged, parallel to the first and just within the western border of the trough. The eastern fold extended along the region now marked by the Green Mountains of Vermont.

The space between these two folds is usually called the Appalachian Valley trough. Probably it was never again entirely submerged, but smaller seas transgressed various parts of it from time to time,

1. Ulrich and Schuchert, Paleozoic Seas and Barriers, pp. 637-638.

particularly in the northern third in Ordovician time. The deposits thus accumulated are almost wholly shales, with occasional rather local bands of impure limestone and some conglomerate. These deposits are found especially in the Rensselaer Plateau and in the "slate belt" of New York and Vermont.

In the region of the present Taconic Mountains proper there seems to have been a gradual depression beginning in the latter part of the Lower Ordovician and extending into Upper Ordovician, during which the limestone and the shales (which later became schists) were deposited[1], the alternation of these beds resulting from changing conditions[2]. Thus, the unusual absence of Stockbridge limestone for fifty miles along the west side of the northern part of the Taconic range would be due to some unusual circumstance affecting the transgression of the sea in that particular region.

The deposition of sediments continued through Ordovician time in the whole Taconic area. Calcareous deposits resulted in the formation of limestone, and the sandstone and shale eventually

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1. Dale, Geology of the North End of the Taconic Range, pp. 189-190.
2. Pumpelly, Geology of the Green Mountains, pp. 30-31.

formed the schists so prevalent in this region. The accumulation of these sediments implies the wearing down of adjacent land.[1]

It will thus be seen that the history of the Taconic area up through Ordovician time is largely one of "rock-making". There were two main crustal movements which involved uplift but no compression, and several minor oscillations, which are shown by the presence of conglomerate which, in turn, implies a temporary emergence sufficient to expose the beds to wave action and thus allow the formation of beach pebbles.[2]

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1. Gregory, The Crystalline Rocks, p. 78.
2. Dale, Geology of the Hudson Valley, pp. 48-49.

Period of orographic disturbances

Taconic "Revolution"

At the close of the Ordovician the type of development in the Taconic region changed. Never again was it subjected to great marine transgression, for a powerful crustal movement brought the Taconic Mountains into existence.

This movement has long been considered to have affected most of eastern North America and is usually referred to as the "Taconic Revolution". According to Schuchert[1], this conception first took written form in the publications of W. W. Mather and of H. D. Rogers in 1838 in connection with the area between Becraft Mountain and Rondout, in southeastern New York. The idea was taken up by Dana, who stated, in 1863, that the "close of Ordovician [was] attended by uplift and folding in eastern North America"[2]. This conception he repeated and enlarged upon in each edition of his Manual of Geology. In the fourth edition he stated:[3] "Mountain-making finally ensued, producing, among its effects, the Taconic Mountain Range along western and northwestern New England, and also the Cincinnati

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1. Schuchert, Significance of Taconic Orogeny, p. 345.
2. Quoted in Clark, A Review of the Evidence for the Taconic Revolution, p. 135.
3. Dana, Manual of Geology, p. 527.

geanticline, besides uplifts in Nova Scotia and New Brunswick. Moreover, there is probably evidence that the Taconic range at the north was but one of a series along the Atlantic border." As this Manual exerted very great influence during the formative period of American geology, continuing to some degree even to the present, there has resulted a concerted opinion among most geologists today that a period of widespread and intense folding accompanied the uplift at the close of the Ordovician period, -- a disturbance of sufficient proportions to be termed a revolution.

Within the last ten years, however, a few geologists, notably T. H. Clark and B. L. Miller, have questioned the propriety of calling this movement a revolution. That there was a definite orogenic movement in the region of western New England and eastern New York State is not disputed, for the existence of land in that area is shown by the fact that after this time fossils found in Maine are unlike those of corresponding age found in New York, thus indicating an isthmus separating the two water bodies. Then, too, sediments of Devonian age to the east and west of this area show a retreating shore line.[1] But that this movement was accompanied by widespread

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1. Gregory, The Crystalline Rocks, pp. 78-79.

folding and uplift throughout eastern North America is seriously open to doubt. There seems to be some conclusive evidence in favor of that view. On the other hand, what evidence there is is far from being sufficient to support the popular conception. Much more data will have to be collected before a final determination can be made.[1] At present it would appear that the objection to the term "revolution" for such a movement is justified. According to present available evidence "Taconic Disturbance" or "Taconic Uplift" is a more suitable designation.

The time when this movement occurred has also been brought up for review. That it was at least late Ordovician can not be questioned, for it is evident that the mountains were folded after the deposition of the youngest sediments they contain. Schuchert's investigations[2] lead him to conclude that the movement started and accomplished most of its work in late Ordovician time, while Miller's researches favor placing it definitely at the end of Ordovician time and before Silurian.[3] We may let this point rest, however, upon the consideration that it is difficult, if not impossible, accurately to delimit

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1. Clark, A Review of the Evidence for the Taconic Revolution; Miller, Taconic Folding in Pennsylvania.
2. Schuchert, Significance of Taconic Orogeny, pp.346-349.
3. Miller, op. cit., pp. 507-509.

the beginning and the end of an orogenic movement. We must be satisfied with a close approximation. In this case we may accept "close of the Ordovician" as the time.

This much is clear, then: That a more or less widespread crustal movement took place sometime near or at the end of the Ordovician period; that it left scattered imprints of its presence in the unconformities which occur at the base of the Silurian in certain localities in western New England, New York, New Jersey, and Pennsylvania; that its greatest work was the raising of the Taconic Mountains, producing a land area which has never since suffered marine submergence; and that this Taconic land area has given its name to the movement which produced it. Although the belt affected included the Green Mountains and the Berkshire Hills as well as the Taconic Mountains, the latter lay along the central axis and so were higher.

This disturbance undoubtedly folded the strata and produced metamorphic rocks and minerals. The question arises, however, as to how much of this folding and metamorphism is due to this orogenic movement, and how much to later ones.[1]

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1. Barrell, Upper Devonian Delta, (2d Paper), pp. 95-96.

Appalachian Revolution

The internal structure and the composition of the rocks of the Taconic region indicate that by Devonian time erosion had worn down the first Taconic Mountains so that they no longer constituted a mountain barrier. The region was almost base levelled.[1] In fact, all of eastern North America was, to a great extent, low-lying toward the latter part of Paleozoic time. This is shown by the wide extent of the coal measures, for the development of coal requires very low, level land areas.[2] Such was the condition of the land when the next orogenic movement took place, the Appalachian Revolution, one of the greatest revolutions of all geologic time.

The Appalachian Revolution is commonly assigned to the close of the Paleozoic Era, allowing it to mark the break between the Paleozoic and the Mesozoic. The orogeny is not, however, confined to just that period of time. Keith would place the real beginning of the revolution late in Cambrian time[3], but the more generally accepted opinion is voiced by Barrell when he says that the orogenic movement began in the

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1. Idem.
2. Martin, James R., Lecture Notes in Geology of North America.
3. Keith, Outlines of Appalachian Structure, pp. 331-332.

Devonian period.[1] At that time mountains were raised on the eastern side of the Appalachian area and to the north, and intrusions of granite and volcanic outpourings took place in Maine, New Brunswick, and Nova Scotia. This movement evinced itself only as an uplift in western New England.[2]

The movement grew in intensity as time went on, and affected an ever increasing area. By Pennsylvanian time the whole Appalachian geosyncline had been deformed. All New England, including the Taconic region, was uplifted and inclined. Great mountains were formed, which extended about 1,500 miles in a southwest direction, even as far as Texas. According to Barrell, the Permian witnessed "only the collapse of the interior geosyncline and the inward march of the conquering mountains".[3] While western North America does not show folding at this time, there is evidence of uplift and a definite unconformity exists between the Paleozoic and Mesozoic eras. To the eastward the movement extended far over the Atlantic Ocean, and there was a revolution in Europe at this same time.[4]

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1. Barrell, Upper Devonian Delta, (3d Paper), p. 253.
2. Keith, Cambrian Succession of Northwestern Vermont, p. 135.
3. Barrell, Upper Devonian Delta, (3d Paper), p. 253.
4. Martin, James R., Lecture Notes in Historical Geology.

The Appalachian Revolution consisted of horizontal movements of the earth's crust which folded the rocks laterally and pushed them up into long high arches separated by narrow troughs. The mountains are characterized especially by the intensity with which the rocks have been folded, piled up, and distorted. This resulted in a vast amount of compression and shortening of the earth's crust, chiefly in a northwest-southeast direction. Considering both sedimentary and plutonic rocks, Keith states his conservative estimate of the shortening to be about forty per cent on the average, or about a two hundred mile shortening of the surface.[1]

As to the cause of this deformation and the reasons for mountain development, there are many theories, such as the Tetrahedral Hypothesis (contraction), Mobile Belts Hypothesis, Theory of Isostasy, and the Taylor-Wegener Hypothesis of Continental Slip. All of them appear to be opposed by one or more great geological facts, while all receive support in some direction.[2]

In general the folds of the Appalachian region are very long and straight. There are some single folds more than one hundred miles long, and the anticlines of the Green Mountains of Vermont are

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1. Keith, Outlines of Appalachian Structure, pp. 334-336.
2. Ibid., passim; Martin, James R., Lecture Notes in Geology of North America.

even longer. The folds, however, are rarely symmetrical, the northwest side usually dipping more steeply than the other side. Faulting accompanied the folding, and is found usually on the northwestern flank of the system. However, the Taconic area is one of the two regions of the Appalachian range where little or no faulting has occurred. The other locality is in Central Virginia. These two were the regions of minimum thrusting. Thrust faulting occurred mostly at the southern end of the range.

Besides folding and faulting, metamorphism took place on a very large scale during the Revolution. The weight of the overlying rocks and the pressure of the mountain building forces combined to overcome the strength of the rocks. Beds flowed or were torn apart, the minerals were recrystallized, and the aspect of the rocks greatly changed. At the northern end of the Appalachian region, and particularly in the Taconic area, scarcely any of the minerals retain their original forms. Limestone was transformed into marble, shale to slates and schists, sandstone to quartzite, and granite and igneous rocks to gneisses and schists.

The different rocks vary greatly in the way they yield to pressure. This is shown, of course, in the way they fold. Heavy beds of solid quartzite,

sandstone, or dolomite bend into broad folds, while thin-bedded rocks like shale, slate, and schist form folds varying from a few feet to minute wrinkles. However, even greater variation is shown in the way they yield to metamorphism. Sediments that contain clay, feldspar, or calcite alter more readily than sandstone and dolomite. This accounts for the complex character of the rocks of the Taconic area. For instance, in a series of interbedded sandstone and shale, the shale may have been well metamorphosed to phyllite or schist, while the sandstone was only silicified. Again, in some of the Vermont marble quarries it is very apparent that a given marble has been in the zone of flowage for calcite, while included dolomite layers were still in their zone of fracture.[1]

East of the Taconic region great masses of granite and other igneous rocks were intruded during the progress of the Revolution.

In the process of deformation during the Appalachian Revolution, the massive Pre-Cambrian area of the Canadian Shield resisted the thrust and folded hardly at all. The brunt of the folding was borne by the thick Cambrian and Ordovician sediments to the east, resulting in their closely folded condition.

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1. Keith, Outlines of Appalachian Structure, pp. 315-316.

The boundary between the two regions is sharp. This same action is shown locally, on a smaller scale, in the Taconic area, where the basement core of Pre-Cambrian rocks has resisted erosion to some extent and has resulted in the northwest trend of those areas where they predominate, while the regions of early Paleozoic formations have the distinctive north-south trend of the Appalachian deformation. Even where the general directions change, there are found differences of ten to twenty degrees in trend between the two areas. The serrate outline of the Paleozoic areas is also one of the results of this differentiation.[1]

The Appalachian region as a whole has been deformed since the Revolution. Triassic faulting affected the northern part particularly, and Cretaceous and Tertiary uplifts bowed up much of the area. However, no element of compression was associated with these later movements, and so they are quite distinct from the Appalachian structures.

The Appalachian Mountains formed by this Revolution comprised one of the great mountain systems of the world. These original mountains are gone, however. The great period of erosion which

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1. Ibid., pp. 320-323.

started in early Mesozoic time has worn them away. As Barrell says, one can "read the epitath which records their greatness in the remnants of formations born of destruction".[1]

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1. Barrell, Upper Devonian Delta, (3d Paper), p. 253.

Mesozoic Peneplanation

As soon as the high Appalachian Mountain system was formed, the process of degradation began. The chemical action of the atmosphere and the action of rain and frost caused the summits to crumble, and the mountain torrents carried the debris down to the valleys, where rivers received it and eventually carried it off to the sea. Barrell's study of Triassic formations showed that erosion was well under way early in Triassic time, for he says it "seems clear that the folded structures of Permian date had suffered profoundly from erosion even by the beginning of Newark deposition".[1] The Triassic period was one of faulting in some parts of the Appalachian region, but thus far it has not been shown that the Taconic region was so affected at that period.

As time went on, degradation continued. By the close of Jurassic erosion had reduced the mountains to a hilly country, planing across the entire thickness of the Newark sediments and across the resistant floor below.[2] As a result of dynamic principles, there is a general law that every stream tends to shape its bed to a slope which allows the stream

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1. Barrell, Upper Devonian Delta, (2d Paper), p. 98.
2. Ibid., pp. 102-103.

just sufficient velocity to carry its load of sediment. This slope is called its profile of equilibrium. As soon as a stream nears its profile of equilibrium it begins to meander. Meander after meander is formed and destroyed until a strip of country many miles wide, in the case of a large river, has been worn down to an almost perfect plane.

Provided there is no uplift, the main streams of a region thus widen their valleys into plains, and extend this process towards their headwaters and along their tributaries. In the meantime the action of the atmosphere and rain and frost action have been wearing down the divides between the streams until they are no longer strongly defined ridges but are flattened, almost imperceptible slopes.

Thus it is evident that in the course of time any region that is exposed to the atmospheric and aqueous agencies of denudation, if there is no renewed uplift of the land, will be reduced to a nearly level surface. The streams in such a region will meander over the broad plains which they have formed. Such a condition is called a peneplain.[1]

This is what happened in the Appalachian region as a whole, and particularly in New England,

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1. Rice, <u>The Geography of Connecticut</u>, pp. 26-29.

including the Taconic region. The constructional topography of the Appalachian Revolution was practically obliterated over the greater part of the area by the long continued denudation of Mesozoic time, so that by the close of the Cretaceous period the region was reduced to "a lowland of faint relief -- a peneplain".[1] The whole country was nearly flat, and no part of it was much above sea level. The only considerable elevations that remained above this lowland were in the White Mountains of New Hampshire and the Black Mountains of North Carolina and their extension in the Blue Ridge Mountains of Virginia.

The form of this peneplain in New England may be seen by climbing any one of the slightly higher ridges. The prevailing feature of the view is the general evenness of the upland surface. The valleys may easily be filled in again in the imagination and the general level of the surface restored. This restored surface should not by any means be perfectly even. Allowance should be made for gentle hills. But the inequalities should be moderate. In southern New England no summits rise above the general level, but the evenness is less marked to the northward. Then occasional isolated peaks stand out conspicuously above

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1. Davis, The Geological Dates of Origin, p. 548.

the general upland. These are called monadnocks, after Mt. Monadnock in New Hampshire. Mt. Greylock is such a monadnock.

That this surface is one of denudation is shown by the fact that it is not at all in sympathy with the structure of the rocks which compose it. That subaërial denudation produced the peneplain is generally accepted, although the possibility of marine denudation is realized. Further study is required before the matter can be definitely settled.[1]

It must not be thought that the land stood absolutely still during the long period of erosion during which the peneplain was produced and that the erosion was all accomplished during one uninterrupted cycle of destruction, for many oscillations of level took place, during which erosion was hastened or retarded.[2]

Barrell objected to the assumption that erosion throughout Mesozoic time was essentially with respect to one base level and that the residuals which have survived above the Cretaceous base level to the present time had previously resisted the erosion of all earlier Mesozoic time.[3] His examinations of the

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1. Ibid., pp. 557-559; Physical Geography of Southern New England, pp. 276-278.
2. Davis, Physical Geography of Southern New England, p. 297.
3. Barrell, Upper Devonian Delta, (2d Paper), pp. 94-105.

Coastal Plain in Maryland and Virginia showed the error of such an assumption. He followed the base of the Potomac formation eastward under the Coastal Plain by means of deep wells, and found that the deposits indicated a fluviatile origin. The surface therefore represents the present inclination of the nearly horizontal base level at the beginning of Comanchean time. The base of the Cretaceous is a marine plain. Clearly, one base level did not persist through the two periods, for the two planes of deposition are inclined to each other at an angle of seventy-nine feet per mile.

The base of the Potomac lies upon a floor prepared by Jurassic erosion. The volume of the Potomac gives some indication of the volume of Comanchean erosion. The base of the Cretaceous deposits measures the warping which took place during Comanchean time. The character of the Potomac sediments implies a Comanchean uplift to the northwest so great as to separate completely the Jurassic and Cretaceous baselevels.

Most of the residuals above the Cretaceous peneplain, according to Barrell, probably lay below the Jurassic base level of erosion, and their continuous endurance above base level since Triassic time can not be implied.

The complete peneplanation of softer formations and the great inroads made on the more resistant areas are, he believed, the product to a very large degree of Cretaceous erosion. The fair degree of preservation of this plain is due chiefly to the comparative recency of the last strong upward movement.

Barrell therefore concluded that the term "Cretaceous" cycle is a broad term for a number of partial cycles extending from the close of the Jurassic, through Comanchean and Cretaceous, and into the early Tertiary.

The erosion probably continued into Tertiary time, for "we must not imagine that changes of elevation took place at the even hours of our geological clock."[1] However, as there is reason to regard Tertiary time as a whole as one of erosion of the uplifted peneplain, it is more as a matter of convenience, rather than with the intention of defining geological dates precisely, that the product of Mesozoic denudation is given the name of "Cretaceous Peneplain".

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1. Davis, The Geological Dates of Origin, pp. 554-555.

Tertiary Uplift and Erosion

According to Davis

Davis was the first to work out a scientific interpretation of the later physiographic history of the Appalachian Province. His explanation, that of peneplanation and subsequent uplift and erosion, quickly gained acceptance, and it has been the foundation of almost all later research along this line.

According to his interpretation[1], early in the Tertiary period of the Cenozoic era the Cretaceous peneplain was uplifted. There was no folding or faulting of the strata, but just a gentle reëlevation. This uplifted peneplain was, however, not a level upland. Its present warped surface shows that the uplift must have been somewhat uneven. The inequality of elevation was comparatively slight, however. The former lowland still touches sea level at Long Island Sound. The topographic atlas shows that the uplands of northwestern Massachusetts reach an altitude of 1600 feet and even 2000 feet in the Taconic range on the western border.[2] The varying altitude of this new upland can be seen along the Atlantic slope from Massachusetts to Georgia, and this shows that the entire peneplain was tilted and somewhat warped when it was uplifted. The highest

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1. Davis, Geological Dates of Origin, passim; Physical Geography of Southern New England, pp. 284-297.
2. Davis, Geological Dates of Origin, p. 566.

part of the entire region was in North Carolina.

Dixon and Drew have given figures for a portion of the uplifted peneplain in New England.[1] In the township of Hinsdale, the peneplain lies at a height of 2050-2100 feet; at Washington Center it falls to 2000 feet. Seven miles to the south-southeast, near Becket Center, it is 1850 feet. Between Sandisfield Center and New Marlborough, about seventeen miles south of Washington, it is 1750 feet. At Tollard Center it is about 1550 feet, and at Blandford Center, about eight miles to the northeast, it is the same. Thus it will be seen that the uplifted peneplain dips from about north-northwest to south-southeast, and that its fall in twenty-five miles is about 550 feet, or at a rate of 22 feet to the mile.

This altitude, however, includes not only the main uplift of early Tertiary time, but also all the oscillations of later date. These oscillations, according to Davis, were not very great and were short-lived. The chief one took place in late Tertiary or early Quaternary time, and allowed the rivers and streams to trench the lowlands produced in the Tertiary cycle.

How the uplift was caused and why it came

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1. Dixon and Drew, <u>Observations on the Physiography of Western Massachusetts</u>, p. 847.

at that particular time, is not known. There is nothing to suggest volcanic action or that the uplift was violent and rapid or attended by earthquakes.

As soon as the elevation of the region began, the rivers entered upon a new cycle of erosion. The uplift gave them a steeper slope, a higher velocity, and a great revival of erosive power. They have ever since been busy carving out a new system of valleys in the mass which had previously been safe below base level. The prevailing south-southeasterly course of the streams is apparently due to the south-southeasterly slope of the uplifted peneplain. The valleys and open lowlands of today were developed in large part in Tertiary time.

The remnants of the Cretaceous peneplain are found today entirely in the belts of the hard rocks, for valleys have been excavated in the regions of the softer rocks. In New England, for instance, there is the broad lowland of the Connecticut Valley cut in the Triassic belt and, in the Taconic region, the Berkshire Valley has been cut in the Stockbridge limestone. Some narrow valleys have been worn even in the harder metamorphic rocks.

It will be seen that the unequal resistance of the rocks has controlled the breadth and form of the valleys cut by this new cycle of erosion. The

Triassic rocks were so weak that they have already been largely reduced to base level again and are in a condition approaching that of a peneplain.

Where the rocks are hard and resist weathering the valleys are still rather narrow and steep-sided, but where the rocks are soft and weather rapidly, the streams have already worn open valleys. Therefore the wide lowlands and the narrow valleys are the work of the same cycle of development, their variation being due to the difference in resistance of the rocks and not to a difference in the height of the mass or in the time of the action.

These contrasted forms are well shown in the upper and lower parts of the Housatonic Valley. The upper part (included in the Berkshire Valley) is in a belt of limestone, and is broad and open. The lower part crosses a region of resistant crystalline rocks and its side slopes are still bold and steep. Here the river has not yet been able to cut down its channel to a smooth and gentle grade. It is because of this condition of its lower course that its upper part is still held almost a thousand feet above sea level.

The depth of the valleys is determined by the amount of uplift the former peneplain received. The valleys are shallow near the coast, where the

upland is but little above sea level. In the interior, where the uplift was greater, the valleys are much deeper.

The strong crystalline rocks are still left, however, as plateau remnants, but the plateau is gashed by innumerable valleys made by small branch streams with steep courses. The uplifted peneplain is no longer a continuous upland surface but has been thoroughly carved into a rugged, hilly country.

The upland of southern New England serves as a type peneplain, now uplifted and well advanced in a second cycle of denudation. Mt. Monadnock is a type example of a residual mountain that rose above the peneplain when it was still a lowland and still continues to dominate the peneplain now that it is an upland. Mt. Greylock in the Taconic region is such a monadnock.

The Berkshire Valley shows an advance in the reduction of the uplifted Cretaceous peneplain towards base level, and the isolated hills of schist which rise above the limestone floor of the valley may be compared with the monadnocks above the Cretaceous peneplain, although, of course, the topography in the Taconic region has not yet reached the condition of old age which it some day will. In Virginia the second set of

residual hills are called catoctins, taking the name of one of them to represent the class. It may be that in time the two terms, monadnock and catoctin, will be used to designate residual hills of the older and younger peneplains.

It may be mentioned here that due to the late or post-Tertiary uplift, before spoken of, all the rivers are now at work trenching their valleys. The larger rivers in the softer rocks have trenched themselves 100-300 feet. The smaller streams, however, except in the neighborhood of the larger rivers, have not sunk their valleys much below the general surface. In the belts of harder rocks the post-Tertiary cycle did little more than to freshen up the slopes.

In general, then, Davis recognizes three cycles of peneplanation, Cretaceous, early Tertiary, and a smaller late Tertiary. Remnants of all three remain so little reduced that the former surfaces can be restored with assurance. Above the Cretaceous peneplain rise residual masses, and below it are cut, locally, the minor peneplain levels during still-stands following the periods of uplift. The underlying assumption is that all peneplaned surfaces are the result of fluvial denudation.

According to Barrell

Although Davis' interpretation was generally accepted, some later writers recognized more than two base levels. As early as 1895 Keith wrote, "Appalachian degradation was marked by at least seven periods of approximate reduction. Each of these produced a vast series of peneplains which appear in various forms at the present day."[1] And in 1918 Shaw wrote, "The conclusion that parts of all peneplains developed since Paleozoic time have endured to the present, and that some of these are early Cretaceous or older seems to be unquestioned; yet data which have been generally available indicate that all peneplains of which remnants exist today are younger than the floor under the Cretaceous with which one or more have been so frequently correlated, and additional data along several lines gathered during the past ten years support this inference." And again, "Evidence as to the ages of the peneplains seems to be fairly harmonious and to indicate ages more recent than those heretofore assigned."[2]

It was about this time that Barrell took up the subject. He gave the matter much study, and was developing several groups of ideas side by side.

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1. Keith, <u>Some Stages of Appalachian Erosion</u>, pp. 524-525.
2. Shaw, <u>Ages of Peneplains of the Appalachian Province</u>, p. 586.

His paper on this subject was only partly written. He had plans made to do extensive field work to see whether his field observations would substantiate or break down his conclusions drawn from laboratory work and study based on topographic maps. But he died in May 1919 in the midst of his work. Little has been done along this line since then, and it is due to his untimely death before he could prove his conclusions beyond doubt, rather than to any other reason, that his views have not been more widely accepted.

Barrell's conclusions are set forth in The Piedmont Terraces of the Northern Appalachians. According to his interpretation, Cenozoic history is much more complex than it is commonly considered to be. He differed with the older views on many points, and especially as to the number of erosion cycles, the origin of the erosion surfaces, and their age. He considered the terraces to be the result of marine denudation, rather than fluvial, and he assigned to the majority of them a post-Miocene age. The one point he had in common with the older view was the recognition of the Cretaceous peneplain, which he called a "topographic plane of reference", which was the result of fluvial denudation. It was over

this that the sea made its first advance. He considered that the marine terraces could be restored from their existing remnants, but that the Cretaceous erosion surface had been too far destroyed to be recognizable except in isolated residual masses.

Barrell studied Western Connecticut by means of projected profiles, and found that from the shore northward the hilltops do not slope upward as remnants of a single warped peneplain, but, on the contrary, that they fall into a series of benches, each member of which is higher than the preceding one. This would indicate that the topography of the region was too complex to be the result of the erosion of a simple warped surface or even of two partial erosion cycles. It may be noted here that all these terraces, however perfect may have been their initial development, have been so dissected by later subaërial erosion that only fragmentary remnants are now to be found.

In the course of his field work along the Atlantic Coastal Plain he found so many unconformities that he concluded that the history of the region could not be interpreted in terms of one Jurassic, one Cretaceous, one early Tertiary, and one later Tertiary base level.

Barrell recognized eleven terraces in Connecticut and western Massachusetts. In the absence of any

definite evidence to the contrary, this may be accepted as final. The names, elevation of the restored margins, and the age of the terraces are as follows.

Becket	2450 feet	Cretaceous	Massachusetts
Canaan	2000 "	"	"
Cornwall	1720 "	Oligocene	Connecticut
Goshen	1380 "	Pliocene	"
Litchfield	1140 "	"	"
Prospect	940 "	"	"
Towantic	740 "	"	"
Appomattox	540 "	"	"
New Canaan	400 "	Pleistocene	"
Sunderland	240 "	"	"
Wicomico	120 "	"	"

It was particularly the character of the topography of the region south of the Cornwall terrace which led Barrell to consider the possibility of a marine origin for the terraces. There is little likelihood of finding any definite evidence of marine denudation in the region of the first three terraces, because they have been exposed to subaërial erosion for too long a time. On the other hand, while evidence of marine erosion might be expected in the region of the younger terraces, the continental glacier probably covered up or carried off most of the evidence.

It will thus be seen that in the Taconic region Barrell recognized two peneplains (the Becket and Canaan terraces) in the area which has long been accepted as the erosion surface of the uplifted and dissected Cretaceous peneplain. According to

Barrell, Davis' "monadnocks above the Cretaceous peneplain" are the eroded remnants of that peneplain.

Barrell's exact opinion as to the age of these peneplains is not absolutely known. H. H. Robinson, who edited Barrell's last paper, stated that from his study of Barrell's published work and his field notes he concludes that Barrell held that if two peneplains are to be recognized, the older may be given an Eocene age and the younger a Miocene. If, however, there was only one peneplain developed, it should be assigned a Miocene age. In any case, the long-recognized peneplain of this region, remnants of which are now to be seen, is of Tertiary development, rather than Cretaceous.

The sequence of events outlined by Barrell is notably different from, and much more complex than, the older scheme. According to Barrell, the Cretaceous "peneplain of reference" was destroyed by subaërial erosion in Tertiary time. A sea then covered Connecticut and Massachusetts to the base of the Green Mountains in Vermont. As this sea retreated marine terraces were formed. The numerous terraces in southern Connecticut are the result of the oscillations of the retreating sea in the Pliocene and Pleistocene epochs.

On the whole, there is no reason to doubt that the Tertiary history of the Appalachian region is as complex as Barrell supposed, but whether all the erosion surfaces under consideration here were originally the result of marine denudation is a question that still has to be determined. It is probable that the conception of the marine origin of the erosion planes will not gain quick acceptance because the physiographic history of the region has for so long a time been well organized on the basis of the fluvial origin of the erosion surfaces, and also because fluvial denudation has come to be looked upon as much more competent than marine denudation to develop extensive erosion planes. Considerable work needs to be done in connection with this problem.

Recently A. M. Pond, following Barrell's teachings, studied the topography of the Taconic Mountains in Vermont, both in the field and by means of projected profiles.[1] She found the upland to consist of a series of terraces which decrease from a 3200 foot elevation on the crest of the range to 2700 (?), 2500, 2000, 1700, 1300, 1100, 900, and 700 foot elevations. The 3200 foot terrace forms the summit of Bear Mountain, Green Peak, and Spruce Peak,

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1. Pond, Preliminary Report on the Peneplanes of the Taconic Mountains of Vermont.

and occurs as spurs on the south and east of Mt. Equinox, and on the north and south side of Dorset Mountain. (All shown on Map A.) She concluded that these erosion levels represented numerous interrupted cycles of erosion interspersed with periods of vertical uplift. They appear to be similar in appearance and elevation to Barrell's marine terraces in Massachusetts and Connecticut. In Vermont, however, there is no positive evidence of the marine origin of the terraces, and as their location is unfavorable to possible exposure to wave action, they probably had a subaërial, rather than a marine, origin.

Pleistocene glaciation

The broad features of the topography of the Taconic region were substantially completed in Tertiary time, but many minor details, such as drumlins, river terraces, waterfalls, and lakes, are due to the events of the Quaternary period, and especially of the Pleistocene epoch.

The topography of this region, and, in fact, of all of New England, is characterized by the rounded contours of its hills and the billowy appearance of the lowlands. There is a notable absence of sharp crests. The rocks are rounded and smooth regardless of their character, and at a distance it is hardly possible to distinguish a hill of gneiss from one of trap or of limestone. Another characteristic of the region is the abundance of lakes and ponds, which are picturesquely located on hills, and in valleys, woodland, and fields. Two more regional characteristics appear in the soil. Not only is there remarkable variety within a small area, but also there is a distinct lack of correspondence between the soil cover and the rock beneath. Nor is there a gradual transition from the soil to the rock beneath, but rather a layer of decomposed material lies directly upon firm, unchanged bed rock.

All these features, so characteristic of New England in general and also of the Taconic area, are due to the presence of the continental glacier in this region during the Pleistocene epoch. Glaciers developed in the Highlands between Hudson Bay and the St. Lawrence River and grew together into a vast ice sheet which moved down over Canada and New England and northeastern United States in general. Over New England the course of the glacier was a little east of south. The exact cause of the development of the continental glacier is not known. Its occurrence implies a change of climate -- a definite cooling of 8-10° F., but although several theories have been advanced to explain this change of climate, no one theory has been universally accepted.[1] Probably it was due to a combination of several factors.

At any rate, just as Greenland is now ice-covered, so New England, including the Taconic region, was once ice-covered with a glacier thick enough to cover all the mountains. As the ice sheet crept over the land it carried along with it all the loose soil in its way, plucked bowlders from projecting ledges, and, in general, wore down the rock surface. The

1. Martin, James R., Lecture Notes in Historical Geology.

rock over which the glacier passed was smoothed and polished, partly by the weight and movement of the ice itself and partly by the bowlders and pebbles that were imbedded in the bottom of the ice sheet. The bowlders sometimes lined or grooved the rocks, as the scratches even now found on traps, granites, quartzites, and gneisses bear witness. The greater part of the exposures of bed rock on the upper parts of the mountains exhibits the smooth surfaces with parallel grooves upon them which is so characteristic of glacial action. These grooves and scratches were made in the direction of the main ice movement, and from them was determined the course followed by the glacier.

The pebbles and bowlders held in the bottom of the ice sheet were worn to a characteristic form. They were flattened and polished, and grooves and striations were worn on one or more sides, leaving the other sides unaffected.

An unusual abundance of bowlders of all sizes, shapes, and colors, and of all materials was strewn broadcast over the whole region covered by the glacier, not only in the valleys, but also on top of the highest hills. Small ones from six inches to three feet in diameter are especially abundant, but there are many from five to ten feet in diameter, and some even exceed twenty feet. The largest ones often

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constitute prominent land marks. They are frequently found nicely balanced on some small facet in an apparently insecure position. These bowlders are usually of different rock from that which underlies them, and when they are traced to their source are found to lie many miles to the south of their place of origin. For instance, dolomite bowlders from Canaan are found in Litchfield, and bowlders in New Haven have traveled from the Berkshire Hills.[1]

There are two particularly prominent bowlder trains in the Taconic region, the Richmond and the Great Barrington. The Richmond bowlder train has been an object of study among geologists for almost a hundred years, and was the subject of much discussion long before the glacial theory of Louis Agassiz was generally accepted.[2]

This Richmond train extends from the Knob (often called Fryes Hill) in the northeastern part of Columbia County, New York (Map C), and extends in nearly a straight line for seven or eight miles S 40° E into Berkshire County, Massachusetts. It can be faintly traced as far again. Its course is diagonally across mountain ridges and valleys. The bowlders are numer-

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1. Gregory, Glacial Geology, pp. 225-241.
2. Benton, The Richmond Bowlder Trains, pp. 17-19.

ous and particularly large for the first seven miles. Then they grow smaller and more scattered. They are composed chiefly of dark green amphibolite blocks, which are all sharply angular, showing little weathering or rounding off of corners. One particularly large bowlder, which lies in a pasture lot two miles north of Richmond Station, is eight feet high, fourteen feet long, and ten feet wide.

The Great Barrington bowlder train begins in Shaker Valley southeast of the Knoll and runs south along the western flank of the Taconic Mountains to Cunningham Hill (Map C). There is then a gap for about eight miles, which has not been examined very carefully. It is believed, however, that the train is not very well defined in this interval. The train is then picked up again and may be followed southward to Great Barrington. It will be seen that the bowlders of this train seem to be concentrated in Shaker Valley and near Great Barrington. These bowlders differ greatly from those of the Richmond train. Here they are well rounded and show the effects of weathering even to a quarter or half an inch beneath the surface. No bowlders of great size are found in this train, the largest being not more than four feet in diameter.

The difference in condition of the bowlders

of these two trains indicates a different history for each. The Richmond blocks, according to Taylor's interpretation, were plucked by the last, or Wisconsin, ice sheet, carried on or in the upper part of the ice, and then strewn about the country. The Great Barrington bowlders, on the other hand, appear to have been water worn before the Wisconsin ice sheet approached and incorporated them into its drift. Then it later deposited them where they now lie.[1]

Unstratified drift, or till, was deposited very generally over the Taconic region. It varies in thickness from a few inches where the topography allowed an even distribution, to over a hundred feet where it has been jammed against hills. This layer of till has in general reduced the minor inequalities of the land surface, and large sand plains have served this same purpose. On the other hand, drumlins of till and eskers and kames of stratified drift have formed hills and ridges which tend to give a rolling or billowy character to what otherwise might be a level stretch of valley.[2]

Berkshire County was within the territory of the eastern limb of the Hudson Valley lobe of the continental glacier. This ice sheet advanced across the

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1. Taylor, Richmond and Great Barrington Bowlder Trains.
2. Gregory, Glacial Geology, pp. 241-247.

County in a southeasterly direction and retreated in a northwesterly direction, as shown by the direction of the striae on the rocks, the alignment of drumlin axes, the position of the stoss side of hills, and by the recessional moraines. It is a general principle that the direction of ice movement at any point near the ice front is about normal to the margin. Therefore, in this case, the general trend of the ice border was presumably northeast and southwest, and it retained this trend during its retreat across the country.[1]

For a long time it was thought that the retreating ice sheet left no recessional moraines in the East as it did in the West. However, Taylor's studies in Berkshire County[2] have shown that while the general retreat was going on across this region the ice front halted fourteen times and formed a series of recessional moraines which correspond in a general way with the recessional moraines of the Great Lakes lobe in the West. While these moraines are distinct individuals with no overlappings, they are fragmentary and relatively slender. They are also quite closely spaced, the average interval between halts in Berkshire County being about three and a half miles. The lines are also intensely sinuous in their courses.

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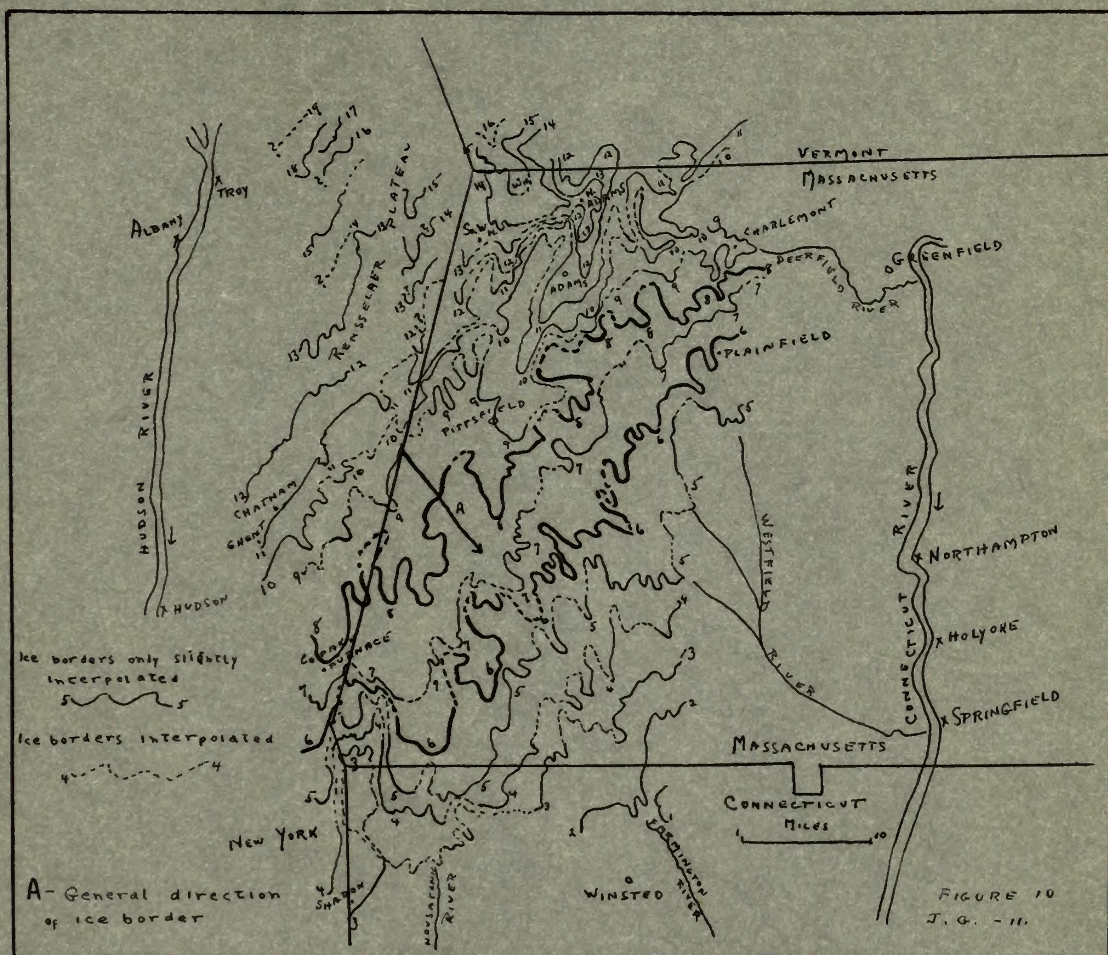
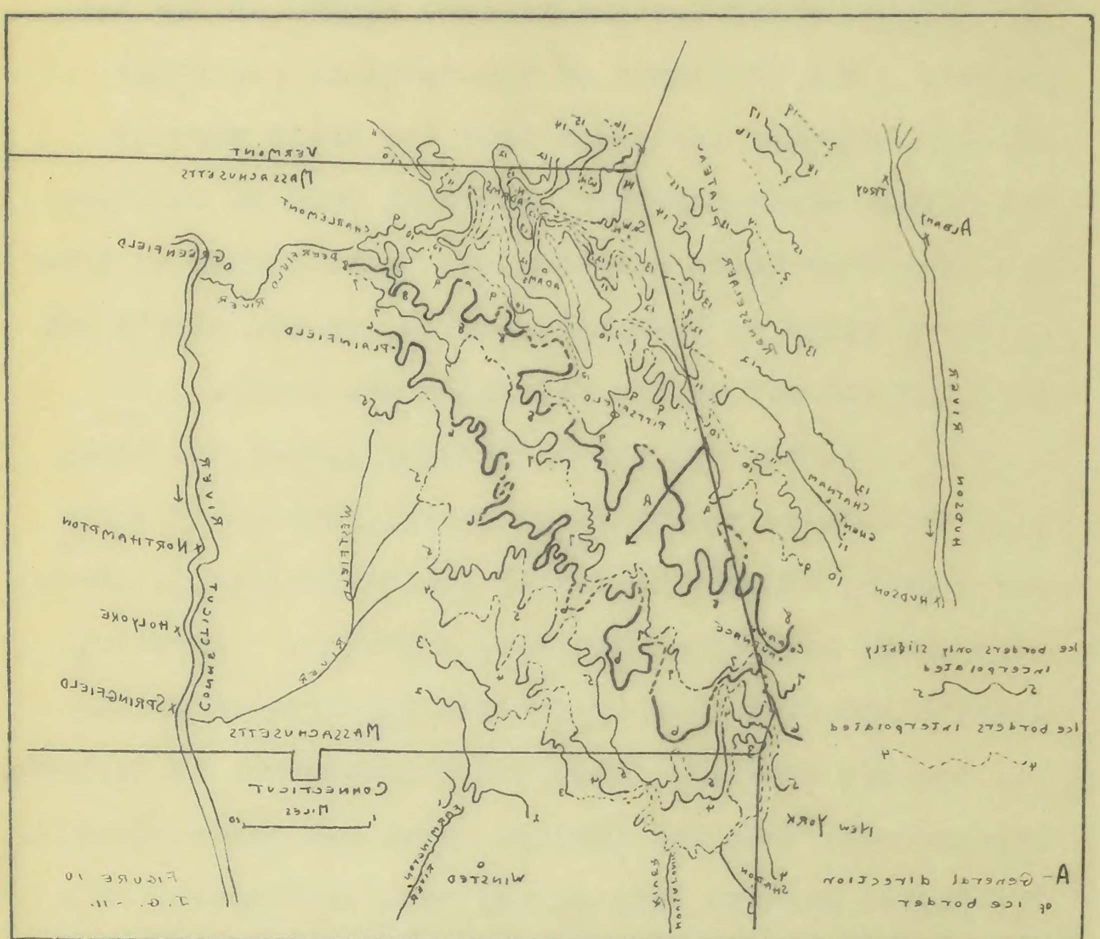
1. Taylor, <u>The Correlation and Reconstruction of Recessional Ice Borders</u>, p. 329.
2. <u>Ibid</u>.

Besides moraines, kames, eskers, eroded river channels, outwash gravel fans, and valley gravel trains all help to determine the various pauses of the ice border. The faintness of the moraines and other border phenomena indicates that the halts were of relatively short duration, although when we consider the fact that there are fourteen halts within an area of fifty miles in Berkshire County, we can hardly say that the retreat of the ice front was rapid.

If the successive halting places had been, say, fifteen or twenty miles apart, instead of three and a half, the continuity of the successive ice borders would have been much more apparent. However, despite the fact that in general the remains of the ice borders here are faint and fragmentary, it happens, fortunately, that two borders stand out quite clearly. The Becket moraine (6th on map page 117) starts at a point about three miles northeast of Tyringham, and is readily recognizable as a continuous line for twenty-five miles, or to a point two or three miles northeast of Plainfield. Its continuity is evident from the closeness of the moraine fragments which comprise it, and from its distinctness from other lines of fragments. The second very evident border is the Lenoxdale moraine (8th on map page 117), which is also about twenty-five miles long and extends from Lenox-



RECESSIONAL ICE BORDERS



RECESSIONAL ICE BORDERS

dale to Glendale to Hillsdale, New York, roughly parallel to the Becket moraine.

Using these as bases for the correlation of other less clearly connected fragments, Taylor has reconstructed the remarkably sinuous recessional ice borders of Berkshire County. The essential points of his map are reproduced on the map on page 117, above referred to. The certainty of the correlation and reconstruction varies in different localities according to the amount of interpolation it was necessary to use. Across Mt. Washington, for instance, it was necessary to interpolate most of the course of the border, for the few fragments of moraines found on the mountain were too far from the surrounding valleys for their connections to be certain. However, the valley deposits on both sides of the mountain were well developed and furnished a good basis for correlation. About the same amount of interpolation was used on Mt. Greylock, but in the rest of the region less interpolation was needed. The work was confined as nearly as possible to valley deposits, for the moraines are nearly always more strongly developed there than elsewhere.

Taylor determined that these branching and interlacing terminal deposits showed that the ice front halted fourteen times in Berkshire County.

The Taconic range and Rensselaer Plateau have not yet been sufficiently studied for mapping, but the unfinished work indicates that when the halts in that region are considered the number will be brought up to twenty or twenty-one.

The mean course of any one of these lines represents the general course of the border of the lobe at that halt. It will be noted that these mean lines are bent from a direct course only by the larger features of topography, such as Mt. Washington. In each line, every point projecting away from the ice field was an ice tongue of rather pronounced development, while every point projecting back toward the field is a re-entrant angle.

It is believed that at the beginning of the Pleistocene the country stood at a higher level than at present, and that when the glacier advanced the great weight of the ice caused the crust of the earth to bend and settle. With the disappearance of the ice, uplift probably took place to some extent.[1]

The ice of the continental glacier scraped off and carried away the soils resulting from rock decomposition, leaving in its place a heterogeneous

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1. Keith, Cambrian Succession of Northwestern Vermont, p. 136.

mass of till. According to Rice[1], this has resulted in a decided deterioration of New England soil as regards adaptation for agriculture. His point of view, however, is not acceptable to all geologists and the question is still debatable. The period of glaciation did, on the other hand, affect the water supply favorably. The new soil is an excellent resevoir for ground water, so that wells are easily made. Besides, the changes brought about in Recent time have provided an unlimited supply of water and of water power, particularly in the Taconic region, and affords an abundant compensation for the rather unfavorable soil.

1. Rice, The Geography of Connecticut, p. 37.

Recent Developments

Because the land was still depressed from the weight of the ice, even after the retreat of the glacier, the sea advanced somewhat over the land, especially in the regions of the great valleys. The exact extent of this submergence has not yet been determined. The most recent development, on a large scale, was the reëlevation of the land area to its present level and the retreat of the sea to its present position. This elevation was greater at the north, the range being from zero at the coast to about 700 feet in northern Vermont.[1] That such a post-Glacial submergence and uplift occurred would seem to be proved by the existence of the gorge which traverses the valley of the Hudson River. It was cut by the river itself, so it must have once been above sea level (before the advent of the glacier). It is now below sea level, and there is ample evidence to show that the sea does not now extend quite so far as it formerly did.[2]

If the Hudson River Valley was uplifted after the glacier disappeared, the Taconic area was no doubt raised up somewhat also.

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1. Fairchild, Pleistocene Marine Submergence, passim.
2. Tarr, Physical Geography of New York State, (3d Paper), passim.

With the reëlevation of the land, the southward-flowing streams acquired increased velocity and, consequently, increased power of erosion and transportation. They began to form new flood plains at a lower level than the older ones. This has resulted in the terraced condition which is so characteristic a feature of Taconic, and New England, topography. Sometimes there is a single abrupt descent from a high terrace to the modern flood plain, while in other localities several terraces rise like a flight of stairs on one or both sides of the stream, according to the kind of rock the stream has met in its meandering.[1]

Another development of the Recent epoch has been the formation of innumerable waterfalls and rapids. These have resulted from the filling of the old valleys by drift, so that when a river flowing on the edge of a plain of drift began to erode its bed, the deepening of the channel was quickly stopped when the river came to the bed rock below the drift. Sometimes streams were turned completely away from their former courses and forced to carve new valleys for themselves for more or less of their course. Then waterfalls or rapids developed wherever ledges of particularly resistant rock retarded the erosive action of the river. Water-

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1. Rice, Geography of Connecticut, pp. 35-36.

falls are short-lived with reference to geologic time, for the streams sooner or later succeed in wearing away the resistant ledges. However, due to the recency of the Glacial epoch, waterfalls are still numerous in the Taconic region.[1]

Another effect of the disturbance of the drainage system by the glacial deposits of drift is seen in the abundance of lakes in the Taconic region. Lakes, like waterfalls, are short-lived. Inflowing streams tend to fill them with sediment, and outflowing ones tend to drain them. The growth of vegetation within them, especially of sphagnum moss, tends to convert them into swamps, then into bogs, and finally into grassy plains underlaid by peat bogs.[2] The innumerable lakes and ponds which still dot the glaciated region are abnormal parts of the drainage system, and, like waterfalls, show the recency of the Glacial epoch.

Despite the great number which still remain, many of the Quaternary glacial lakes have already been drained. These former lakes left behind deposits of finely stratified clay in the form of level lake beds and horizontal sand terraces. Glacial Lake Bascom

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1. _Ibid._, pp. 36-37.
2. Gregory, _Glacial Geology_, pp. 247-250.

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1. Ibid., pp. 36-37.
2. Gregory, Glacial Geology, pp. 287-290.

was responsible for the terraces on Mt. Greylock and others in that vicinity[1], and shore lines of former lakes are very conspicuous in Dorset Hollow, Manchester, and Sunderland, Vermont, at the 1000, 1100, and 1200 foot levels.[2]

The comparatively recent scarring of Mt. Greylock by landslides is not only a very conspicuous feature of the landscape, but is also a very striking bit of evidence to show that the hills are still being subjected to erosional processes. The eastern side of the mountain is the steepest, rising 1400 feet in two-fifths of a mile. It is on this slope that three large and eight small landslides have occurred within the space of a mile.

As described by Cleland[3], the three large slides occurred on August 20, 1901. The steep slope, the fissile character of the Greylock schist and the rotten micaceous Bellowspipe limestone below it, the abundance of loose talus, and the sparse growth of trees, combined with the unusually heavy summer rain, all joined to present very favorable conditions for such an occurrence. Then a cloudburst occurred to give an unusually large amount of water to add to the

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1. Dale, <u>The Geological History of Mt. Greylock, pp</u>. 244-247.
2. Dale, <u>The Commercial Marbles of Western Vermont</u>, pp. 70-71.
3. Cleland, <u>The Landslides of Mt. Greylock</u>, pp. 513-515.

weight of the mass and to act as a lubricant. All three slides occurred within a few minutes of each other. The north slide is about fifty feet wide at the top and extends for 1500 feet down the mountain side, gradually widening to about 200 feet at the base.

The removed material was not piled up with a backward slope toward the mountain as is usually the case, for there was such a large amount of water present that it was able to spread the debris and deposit it over the valley below.

Recapitulation

The early history of the Taconic Mountain region is that of a profoundly subsiding trough into which sediments were being carried and deposited from the surrounding Archaean mountains. Quartzite has resulted from the Lower Cambrian sedimentation, and limestone and marble from the Cambro-Ordovician calcareous deposits. The Ordovician argillaceous sediments have produced the Berkshire schist, while minor changes during that period have resulted in the formation of Bellowspipe limestone and Greylock schist locally. Orogenic movements took place at intervals during all this time, but the first one of any magnitude came at or near the close of the Ordovician period. This movement raised high above sea level the area under consideration and formed the first Taconic Mountains. The forerunners of a greater orogenic movement began to evince themselves in Devonian time, and by the end of the Paleozoic Era the Appalachian Revolution, one of the greatest revolutions in geologic history, was in full progress. This revolution rejuvenated the Taconic Mountains, so that they, as part of the Appalachian Mountains, constituted one of the greatest mountain systems of the world. This period of orogeny resulted not only in

folding but also in faulting, metamorphism, and in the production of secondary structures of several kinds.

Beginning with the Mesozoic Era, the history of these mountains has been chiefly one of destruction. As soon as the region was exposed above sea level denudation began, and occasional uplifts have served to give renewed power to this process. At least once, and probably several times, the region has been base-leveled. The present topography is the result of the erosion of these former peneplains. Erosion has gone on to such an extent that today the very roots of the former great mountains are revealed.

The minor features of the landscape are due to the action of the continental glacier which buried the Taconic region under ice during the Pleistocene epoch. Today one can recognize the workings of geologic processes in the gradual disappearance of glacial lakes and waterfalls and the wearing down of the mountains by landslides.

ECONOMIC FEATURES

Limestone

The Stockbridge limestone is irregular in both composition and structure. In general the lower part is dolomitic or "high magnesium" and the upper part is calcitic or "high calcium", but there is some interbedding of the two varieties in the upper part. The folding of the beds throughout the formation is generally intricate. A practical difficulty, which is common to all glaciated regions, may be noted here, and that is that a large part of the limestone area is covered with glacial deposits too thick to be removed, and therefore much of the limestone is not available for use.

Pure calcite ($CaCO_3$) is one of the chief minerals needed in the manufacture of lime, and much of the calcite limestone in the Taconic region is used for that purpose. However, some varieties of limestone contain too many accessory minerals, such as quartz, mica, pyrite, and graphite, and so have to be discarded. Some varieties have to be discarded because their texture makes them unfit for burning in upright kilns or because they hydrate on exposure soon after burning.

Dolomite, a calcium and magnesium carbonate ($CaMg(CO_3)_2$), is also used in the manufacture of lime,

for both "finishing" and "common" lime. However, some dolomitic limestones, like the calcitic, have objectionable minerals and so have to be discarded, and some can not be used because under fire they pass into fine sand, which chokes the draft and prevents calcination.

The amount of limestone that has to be discarded is of great economic importance, because the cost of quarrying covers both the usable and the discarded rock, and so the percentage of discarded rock directly affects the cost of that which can be used. The need, then, is for a series of beds giving a minimum percentage of rock unsuitable for lime.[1]

One of the striking features of the limestone belt is the change, which occurs between Stockbridge, Massachusetts, and Canaan, New York, and also near South Williamstown, from a calcite marble to a granular limestone. This change is probably due to the same diminishing crustal pressure to which is attributed the general decrease in metamorphism west from the central axis of crystalline rocks in the Green Mountain Range.[2]

Some marble found at West Stockbridge, Lanesborough, and New Ashford, is flexible and

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1. Dale, The Lime Belt of Massachusetts, pp. 1-48.
2. Ibid., p. 56.

elastic, especially when wet from sawing and polishing. Some of the property is lost when the marble is dry. Such marble, however, is rather rare.[1]

The Stockbridge limestone extends the entire length of the Taconic region, from Connecticut to Vermont. In Connecticut it is important as a source of lime and also as a building stone. The State Capitol at Hartford is built of marble quarried at Canaan.[2] This formation is of especial economic importance in the southern part, however, for in it occur the iron mines of Salisbury, Connecticut, and of Columbia and Dutchess Counties, New York. These will be discussed later.

Most of the limestone quarried in Massachusetts is used for burning into lime, as at the quarries at West Stockbridge, New Lenox, Farnham Station, and Cheshire. The limestone at North Adams is used chiefly for marble dust. Some limestone is used for flux, and some is quarried for agricultural use, especially for the purpose of neutralizing the acidity of the soil. The limestone is also important as a building stone.[3]

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1. Dewey, <u>Notice of the Flexible or Elastic Marble of Berkshire County</u>, p. 241.
2. Gregory, <u>The Crystalline Rocks</u>, p. 89.
3. Dale, <u>Lime Belt of Massachusetts</u>, pp. 59-60; Day, <u>Stone</u>, p. 403; Ries, <u>The Limestone Quarries</u>, pp. 803-806.

Very little of the Vermont limestone is used for building purposes. Small outcrops are being used by farmers for neutralizing the soil. Most of the limestone quarried is used for chemical purposes, especially for precipitated lime, tanning, bleaching powder, gelatine and glue making, photographic plate manufacture, fiber for shoes, mordants, paint, oil, varnishes, and for building lime and plaster.[1]

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1. Jacobs, The Lime Industry in Vermont, pp. 158-159.

Marble

Marble has been quarried in Vermont for more than a hundred and forty years, and from the beginning this State has led all the others in the production of marble. Formerly it had a monopoly, but now over eighteen states quarry and sell good marble, especially Colorado, Georgia, and Tennessee. In absolute quantity some other states exceed Vermont, but much of the other marble can be used only for building stone, while Vermont marble is of such quality that it can be used in statuary and monuments, and therefore it has a much greater value.

The first quarry was opened at Dorset in 1785, and the marble was used for fire jambs, chimney backs, and for hearths and lintels. Other quarries soon opened up, and by 1841 there were nine.[1]

The marble district lies west of the Green Mountain Range, in Bennington, Rutland, and Addison Counties, and the largest amount of marble is quarried in Rutland County. The longest marble belt lies partly in the Vermont Valley between the Green Mountains and the Taconic Range, and partly between the Taconic Range and the intermediate ridges from Pine Hill to Danby Hill. This belt extends north of the

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1. Perkins, Report on the Marble, etc. Industries of Vermont, pp. 10, 16; History of the Vermont Marble Industry, p. 161.

Taconic Mountains and ends between Middlebury and Bristol, having a total north-south length of about 80 miles. Within the Taconic Range itself is the West Rutland belt of marble, occupying a minor longitudinal valley carved by the Castleton River. This belt is six miles long and half a mile wide. Besides these there are other smaller marble areas within the Taconic Range.[1] We are not concerned here with the northwestern marble belt of Vermont, as that lies outside of the Taconic region.

The chemical composition of marble varies primarily according to whether it consists of calcite or of dolomite or of both. White calcite marble is almost entirely calcium carbonate, while in white dolomite marble carbonate of magnesium takes the place of some of the calcium carbonate. The colored marbles of these contain small percentages of other minerals, such as graphite, quartz, hematite, limonite, magnetite, pyrite, muscovite, actinolite, and tremolite.[2]

A very important feature of the marble belt is the fact that the upper part of the marble is always found, except where faulting has occurred, next to the schist, and the lower part next to the underlying dolomite. At present the most productive quarries are near the schist.[3]

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1. Dale, The Commercial Marbles of Western Vermont, p. 55.
2. Ibid., p. 4.
3. Ibid., p. 57.

In 1914 there were 86 varieties of marble quarried in Vermont. These fall into the following twelve petrographic groups:[1]

1. Calcite marbles
2. Graphitic calcite marbles
3. Muscovitic " "
4. Chloritic and muscovitic calcite marbles
5. Actinolite calcite marbles
6. Calcite marbles with minute dolomitic lenses and beds, usually graphitic
7. Brecciated calcite and dolomite marbles with hematitic cement
8. Carbonaceous slightly dolomitic unmetamorphic calcite marble
9. Graphitic dolomite marble
10. Hematitic untwinned dolomite marble with quartz grains
11. Serpentine (Vermont verde antique)
12. Chrome mica (fuchsite) schist

For a long time most of the marble from East Dorset has been shipped to Philadelphia for building purposes. The West Rutland marble is used chiefly for monuments and tombstones. Proctor marble is used largely for these purposes and also for electrical switchboards.[2] Some marble is used just for construction purposes, while a great deal is suitable for monuments and statuary. Serpentine marble is popular for columns, wainscoting, counter tops, base, and tiling. The waste of some quarries is sold as crushed stone.

Some of the buildings constructed from Vermont marble are the New York Public Library (except the

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1. *Ibid.*, p. 145.
2. Ries, *The Limestone Quarries*, pp. 806-810.

approaches), the Harvard Medical School group, the John Hay Memorial Library of Brown University, Memorial Continental Hall, Washington (except the northwest corner), including thirteen monolithic 27-foot columns, the Royal Bank of Canada, Toronto, and the Art Association Building, Montreal.

Vermont marble was used for interior decorative work in the Soldiers and Sailors Monument on Riverside Drive, New York, and in the New York Public Library, and for the mantels in the United States Senate Office Building, Washington.[1]

Along with Vermont, Massachusetts was one of the pioneers in the marble field. Today, however, most of the marble industry in this State is confined to two quarries, both at Lee. The most important product from this marble field at the present time is headstones for graves of soldiers in the United States cemeteries, but the marble is also used for building, to a slight extent, and for tiling, terrazzo, and mosaic flooring. The former importance of this marble region, however, will be seen from the following list of buildings which were constructed from marble from the Lee quarries: Massachusetts State House Annex, New York City Clearing House, Metropolitan Life In-

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1. Dale, The Commercial Marbles of Western Vermont, passim.

surance Company Annex, New York, Public Library, New Rochelle, New York, Town Hall, Milford, Connecticut, Public Library, Lee, Massachusetts, and many public buildings in Philadelphia.[1]

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1. Dale, The Lime Belt of Massachusetts, pp. 60-64.

Slate

The slate belt of Eastern New York and Western Vermont lies between the Taconic Mountains on the east and Lake Champlain and the Hudson River on the west. It extends from the Hoosic River on the south to the towns of Benson and Hubbardton, Vermont, on the north. However, good slate is hardly obtainable south of Shushan and Greenwich, in Washington County, New York, so the actual length of the slate belt may be said to be about 45 miles. Its width at the north is about eleven miles, and at the south six miles, averaging a little over seven miles. The whole area is therefore about 320 square miles, lying in the counties of Washington, New York, and Rutland, Vermont.[1] Slate is also found within the western Taconic region, as at Hoosick, Rensselaer County, New York. Quarries of roofing slate have been opened up also in the Taconic Range in many places, particularly at New Lebanon.[2]

Pennsylvania leads the United States in slate production, but Vermont is second, with no other state coming near her. However, while the total sales of slate in Pennsylvania greatly exceed those of Vermont, it is said that for those uses

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1. Dale, The Slate Belt, p. 164.
2. Newland, The Mineral Resources, pp. 244-245.

which require large slabs, such as are needed for billiard table tops, tanks, and the like, the Vermont slate is more in demand. Then too, there are certain colors, as the purple and unfading green, which are abundant in Vermont and are found nowhere else. In the production and sale of these Vermont has a monopoly.[1]

The slates appear in two formations. The larger one is Lower Cambrian. These are the "sea green" and "unfading green", the purple, and the mottled slates. They are quarried almost exclusively on the Vermont side of the slate belt. The second formation is the Ordovician. These are the red slates and the "bright green", and they occur in their best development on the New York side. Black slates occur in Benson, but their age is uncertain, although it is either Cambrian or Ordovician.[2]

The slates differ somewhat in hardness, homogeneity, and cleavage, but the greatest variation is found in their color. No other slate belt shows so many colors in an area of equal size. The commercial names under which the slate is sold are descriptive of each kind: sea green, unfading green, uniform green, bright green, red, bright red, cherry

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1. Perkins, Building and Ornamental Stones, p. 8.
2. Dale, The Slate Belt, p. 176; Slate Deposits, p. 71.

red, purple, purple variegated, variegated, and mottled.[1]

The true sea green is found only in Vermont. It is used as a roofing slate but fades and changes color, after two or three years' exposure, to brown or brownish yellow hues. It is therefore not very popular on the whole, although some prefer it. The unfading green has a pale greenish-gray color. It shows but a slight change on exposure to the weather, and so is valued for roofing slate.

The best known product of the New York quarries is the red slate. This is practically restricted to Washington County. Its color is a hematite red, and is as nearly permanent under atmospheric conditions as any known slate. It also has a silky luster. It is very popular as roofing material, and as the supply is limited, it commands a high price.

The purple slate has a dark purplish brown color. The variegated has a pattern of purple and green in irregular mixture.[2]

Many of the quarries produce only roofing

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1. Day, Stone, p. 435.
2. Newland, The Mineral Resources of State of New York, pp. 243-244.

slate, while others produce this and the more compact, less easily split stone which is known as mill stock.[1]

1. Perkins, Building and Ornamental Stones, p. 9.

Iron Ore

The well known "Salisbury iron" is smelted from limonite ores mined in northwestern Litchfield County, Connecticut, Berkshire County, Massachusetts, and portions of Dutchess and Columbia Counties, New York. As the ore was first mined near Salisbury, Connecticut, and for a long time the largest amount of ore came from there, the name of that town has been given to the ore of the whole region.

The first forge was set up in 1734 to smelt iron mined that year, and from that time on the limonite of the region has been in demand, by local furnaces at least. Even today, in spite of the rather low grade of the ores (40 to 50 and exceptionally 55 to 57 per cent of metallic iron) and the recent vast development of iron mining within the Lake Superior region, the Salisbury mines continue to be worked, although the output, to be sure, is comparatively small. This is due in large part to the peculiar properties of the ore, particularly its high content of manganese and its low percentage of phosphorus, but it is also due to the methods of smelting and founding which are used, for the furnaces here still use charcoal as a fuel. The pig iron produced from these ores is especially adapted to the manufacture of car wheels.

The greater number of the iron mines are located either at or near the boundary of Berkshire schist and Stockbridge limestone, and it is a significant fact that the more important ore beds form a nearly continuous circle about the base of Mt. Washington.

A subordinate group of iron mines, called the Richmond group, was situated in the West Stockbridge Valley, Massachusetts, but of these only one was still being operated in 1907.

There has been some controversy, from the time of Dana to the present, as to the origin of these limonite ores. The view now favored is that advanced by Hobbs, that the iron contained in the ores was introduced, through the agency of solutions, from some outside source, probably the pyrite contained in the Berkshire schists of Mt. Washington, and that the ores were formed as replacements, the limonite replacing the Berkshire schist. The time of the deposition of the ores was probably late or post-Pleistocene.[1]

1. Hobbs, The Iron Ores of the Salisbury District.

SUMMARY

In the foregoing thesis I have given a general description and history of the Taconic Mountains of New England as conceived by me after surveying the literature on the subject.

In the Introduction I told of the awakening of interest in the geology of this region and briefly reviewed the work of the earliest geologists in this field. Then followed a short history of the Taconic controversy and a statement of the work of James D. Dana both in that connection and in the Taconic field in general.

I then gave a physiographic description of the mountains, and followed that with a stratigraphic description of the five divisions into which the region is naturally divided. A brief structural description, illustrated by cross sections, then followed. In these stratigraphic and structural descriptions the mass of specific details was purposely omitted. The general reader will, I hope, gain an adequate understanding of the region from this paper, and one who seeks further details can easily find them in the works to which he is herein referred.

The history of the Taconic region constitutes the major part of this paper. In this section I have traced the development of the Taconic Mountains through

all the vicissitudes of geologic time from Archaean to the present. In instances where there are different interpretations of the history of the region I have set forth the more important conceptions.

Lastly, the chief economic features of the region were touched upon briefly.

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Harvard College Museum Comparative Zoology Bulletin 16 (1891), pp. 173-184.
The Geology of Hoosac Mountain and Adjacent Territory
United States Geological Survey Monograph XXIII (1894), pp. 35-108.
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Bulletin of Geological Society of America 14 (1904), p. 554.

Map A Taconic Mountains of New England Myrtle L. Wilcock

THE TOPOGRAPHIC MAPS OF THE UNITED STATES

The United States Geological Survey is making a topographic atlas of the United States. This work has been in progress since 1882, and more than 38 per cent of the area of the country, excluding outlying possessions, has now been mapped. The areas mapped are widely distributed, every State being represented, as shown on the progress maps accompanying each annual report of the Director.

This atlas is being published in sheets of convenient size, about 16½ by 20 inches. The four-sided area of land represented on an atlas sheet is bounded by parallels and meridians and is called a *quadrangle*. The quadrangles mapped cover 1° of latitude by 1° of longitude, 30′ of latitude by 30′ of longitude, 15′ of latitude by 15′ of longitude, or smaller areas, the size of the area mapped depending on the scale used. Several scales are employed. The smallest scale, that used for quadrangles covering 1°, is 1:250,000, or very nearly 4 miles to an inch—that is, 4 linear miles on the ground is represented by 1 linear inch on the map. This scale is used for maps of the desert regions and some other parts of the far West. For the greater part of the country, which is mapped by quadrangles covering 30′, a larger scale, 1:125,000, or about 2 miles to an inch, is employed. A still larger scale, 1:62,500, or about a mile to an inch, is used for quadrangles covering 15′, the unit selected for mapping thickly settled or industrially important areas. A fourth scale, 1:31,680, or one-half mile to an inch, is employed for maps that are to be used in connection with irrigation or drainage, and a few maps of mining districts are published on still larger scales.

A topographic survey of Alaska has been in progress since 1898 and nearly 30 per cent of its entire area has now been mapped. One-third of the area mapped, or 10 per cent of the Territory, has been covered only by reconnaissance work, the results of which have been mapped on a scale of about 10 miles to an inch. The maps of nearly all the remaining two-thirds of the surveyed area have been published on a scale of 1:250,000, or about 4 miles to an inch. These maps are large, each representing 2° of latitude by 4° of longitude. A few areas that are of economic importance, aggregating about 3,000 square miles, have been surveyed in greater detail and mapped on a scale of 1:62,500, or about a mile to an inch.

A survey of the Hawaiian Islands was begun in 1910 and the resulting maps are being published on a scale of 1:62,500.

The features shown on these atlas sheets or maps may be classed in three groups—(1) *water*, including seas, lakes, rivers, canals, swamps, and other bodies of water; (2) *relief*, including mountains, hills, valleys, and other elevations and depressions; (3) *culture* (works of man), such as towns, cities, roads, railroads, and boundaries. The conventional signs used for these features are shown below, with explanations. Variations appear on some earlier maps.

All water features are printed in *blue*, the smaller streams and canals in full blue lines and the larger streams, lakes, and the sea in blue water-lining. Intermittent streams—those whose beds are dry at least three months in the year—are shown by lines of dots and dashes.

Relief is shown by contour lines in *brown*. A contour on the ground passes through points that have the same altitude. One who follows a contour will go neither uphill nor downhill but on a level. The contour lines on the map show not only the shapes of the hills, mountains, and valleys but also their elevations. The line of the sea coast itself is a contour line, the datum or zero of elevation being mean sea level. The contour at, say, 20 feet above sea level would be the shore line if the sea were to rise or the land to sink 20 feet. On a gentle slope this contour is far from the present coast; on a steep slope it is near the coast. Where successive contour lines are far apart on the map they indicate a gentle slope; where they are close together they indicate a steep slope; and where they run together in one line they indicate a cliff.

The manner in which contour lines express altitude, form, and grade is shown in the figure below.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay that is partly inclosed by a hooked sand bar. On each side of the valley is a terrace into which small streams have cut narrow gullies. The hill on the right has a rounded summit and gently sloping spurs separated by ravines. The spurs are truncated at their lower ends by a sea cliff. The hill on the left terminates abruptly at the valley in a steep scarp. It slopes gradually back away from the scarp and forms an inclined table-land, which is traversed by a few shallow gullies. On the map each of these features is indicated, directly beneath its position in the sketch, by contour lines.

The contour interval, or the vertical distance in feet between one contour and the next, is stated at the bottom of each map. This interval differs according to the character of the area mapped; in a flat country it may be as small as 5 feet; in a mountainous region it may be 250 feet. Certain contour lines, every fourth or fifth one, are made heavier than the others and are accompanied by figures stating elevation above sea level. The heights of many points, such as road corners, summits, surfaces of lakes, and bench marks, are also given on the map in figures, which express the elevations to the nearest foot only. More exact elevations of bench marks, as well as geodetic coordinates of triangulation stations, are published in bulletins issued by the Geological Survey. A bulletin pertaining to any State may be had on application.

The works of man are shown in *black*, in which color all lettering also is printed. Boundaries, such as those of a State, county, city, land grant, township, or reservation, are shown by continuous or broken lines of different kinds and weights. Public and through roads are shown by fine double lines; private and poor roads by dashed double lines; trails by dashed single lines.

Each quadrangle mapped for the topographic atlas is designated by the name of a principal town or of some prominent natural feature within the quadrangle, and on the margins of the maps are printed the names of adjoining quadrangles for which atlas sheets have been published or are in preparation. The sheets are sold at 10 cents each in lots of less than 50 copies or at 6 cents each in lots of 50 or more copies, whether of the same or of different sheets.

The topographic map is the base on which the geology and the mineral resources of a quadrangle are represented, the maps showing these features being bound together, with a description of the quadrangle, to form a folio of the Geologic Atlas of the United States. Circulars showing by index maps the published topographic atlas sheets and geologic folios covering any State or region will be sent free on application.

Applications for maps or folios should be accompanied by cash—the exact amount—or by post-office money order and should be addressed to—

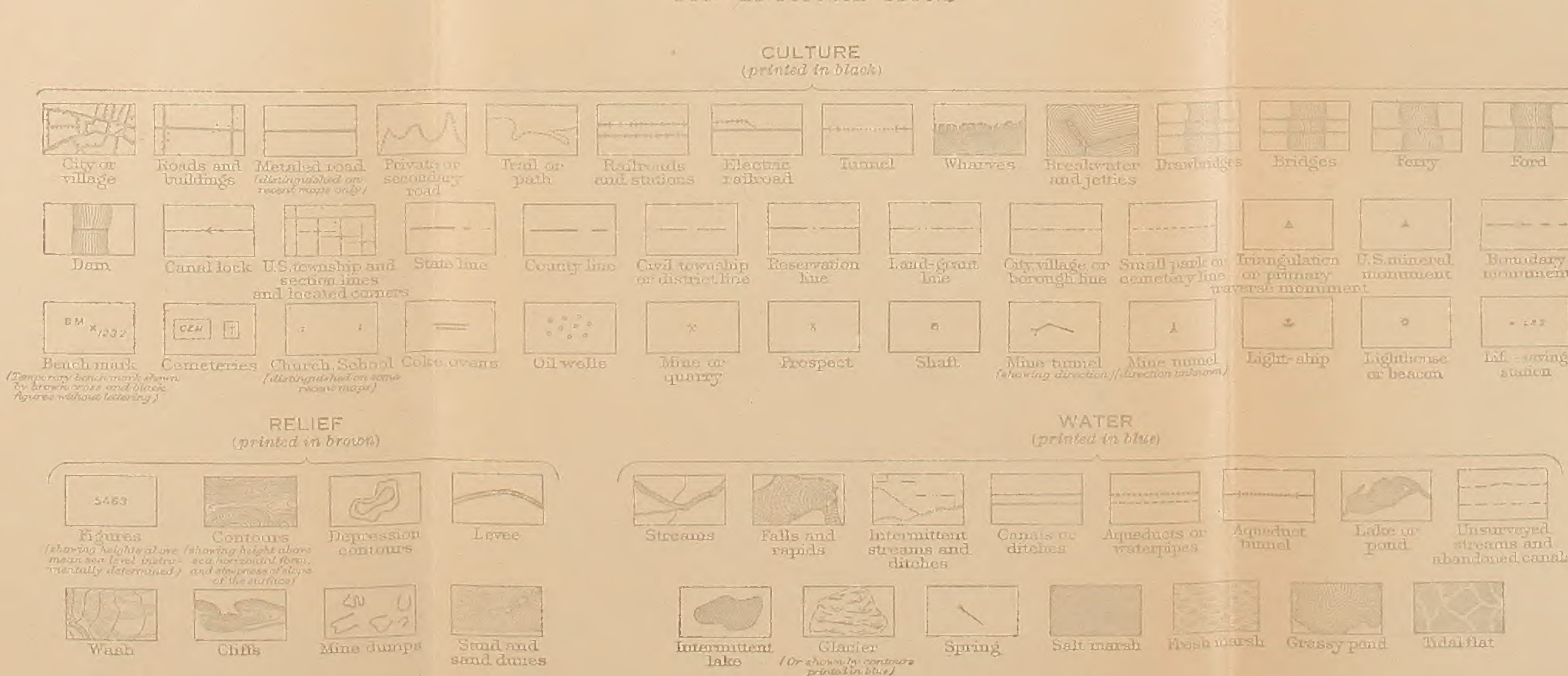
THE DIRECTOR,

United States Geological Survey,

Washington, D. C.

January, 1913.

CONVENTIONAL SIGNS



U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

TOPOGRAPHY

NEW YORK–VERMONT
METTAWEE QUADRANGLE

Henry Gannett, Chief Topographer.
H.M. Wilson, Geographer in charge.
Triangulation by the U.S. Coast and Geodetic Survey,
S.S. Gannett and Geo. T. Hawkins.
Topography by E.B. Clark, G.E. Hyde, Jas. McCormick,
J.H. Jennings and J.W. Thom.
Surveyed in 1892-93-94 in cooperation with the State of New York.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

Miles

Kilometers

Contour interval 40 feet.
Datum is mean sea level.

Edition of Jan. 1903, reprinted Mar. 1913

METTAWEE

Map B   Taconic Mountains of New England   Myrtle L. Wilcock

THE TOPOGRAPHIC MAPS OF THE UNITED STATES

The United States Geological Survey is making a standard topographic atlas of the United States. This work has been in progress since 1882, and its results consist of published maps of more than 40 per cent of the country, exclusive of outlying possessions.

This topographic atlas is published in the form of maps on sheets measuring about $16\frac{1}{2}$ by 20 inches. Under the general plan adopted the country is divided into quadrangles bounded by parallels of latitude and meridians of longitude. These quadrangles are mapped on different scales, the scale selected for each map being that which is best adapted to general use in the development of the country, and consequently, though the standard maps are of nearly uniform size, they represent areas of different sizes. On the lower margin of each map are printed graphic scales showing distances in feet, meters, and miles. In addition, the scale of the map is shown by a fraction expressing a fixed ratio between linear measurements on the map and corresponding distances on the ground. For example, the scale $\frac{1}{62,500}$ means that 1 unit on the map (such as 1 inch, 1 foot, or 1 meter) represents 62,500 similar units on the earth's surface.

Although some areas are surveyed and some maps are compiled and published on special scales for special purposes, the standard topographic surveys for the United States proper and the resulting maps have for many years been divided into three types, differentiated as follows:

1. Surveys of areas in which there are problems of great public importance—relating, for example, to mineral development, irrigation, or reclamation of swamp areas—are made with sufficient accuracy to be used in the publication of maps on a scale of $\frac{1}{31,680}$ (1 inch = one-half mile), with a contour interval of 1, 5, or 10 feet.

2. Surveys of areas in which there are problems of average public importance, such as most of the basin of the Mississippi and its tributaries, are made with sufficient accuracy to be used in the publication of maps on a scale of $\frac{1}{62,500}$ (1 inch = nearly 1 mile), with a contour interval of 10 to 25 feet.

3. Surveys of areas in which the problems are of minor public importance, such as much of the mountain or desert region of Arizona or New Mexico, are made with sufficient accuracy to be used in the publication of maps on a scale of $\frac{1}{125,000}$ (1 inch = nearly 2 miles), with a contour interval of 25 to 100 feet.

A topographic survey of Alaska has been in progress since 1898, and nearly 37 per cent of its area has now been mapped. About 10 per cent of the Territory has been covered by reconnaissance maps on a scale of $\frac{1}{625,000}$ or about 10 miles to an inch. Most of the remaining area surveyed in Alaska has been mapped on a scale of $\frac{1}{250,000}$, but about 4,000 square miles has been mapped on a scale of $\frac{1}{62,500}$.

About half of the Hawaiian Islands has been surveyed, and the resulting maps are published on a scale of $\frac{1}{62,500}$.

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Relief is shown by contour lines in brown, which on some maps are supplemented by shading showing the effect of light thrown from the northwest across the area represented, for the purpose of giving the appearance of relief and thus aiding in the interpretation of the contour lines. A contour line represents an imaginary line on the ground (a contour) every part of which is at the same altitude above sea level. Such a line could be drawn at any altitude, but in practice only the contours at certain regular intervals of altitude are shown. The line of the seacoast itself is a contour, the datum or zero of altitude being mean sea level. The 20-foot contour would be the shore line if the sea should rise 20 feet. Contour lines show the shape of the hills, mountains, and valleys, as well as their altitude. Successive contour lines that are far apart on the map indicate a gentle slope; lines that are close together indicate a steep slope; and lines that run together indicate a cliff.

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The contour interval, or the vertical distance in feet between one contour and the next, is stated at the bottom of each map. This interval differs according to the topography of the area mapped: in a flat country it may be as small as 1 foot; in a mountainous region it may be as great as 250 feet. Certain contour lines, every fourth or fifth one, are made heavier than the others and are accompanied by figures showing altitude. The heights of many points—such as road corners, summits, surfaces of lakes, and bench marks—are also given on the map in figures, which show altitudes to the nearest foot only. More exact altitudes—those of bench marks—as well as the geodetic coordinates of triangulation stations, are published in bulletins issued by the Geological Survey.

Lettering and the works of man are shown in black. Boundaries, such as those of a State, county, city, land grant, township, or reservation, are shown by continuous or broken lines of different kinds and weights. Metaled roads are shown by double lines, one of which is accentuated. Other public roads are shown by fine double lines, private and poor roads by dashed double lines, trails by dashed single lines.

Each quadrangle is designated by the name of a city, town, or prominent natural feature within it, and on the margins of the map are printed the names of adjoining quadrangles of which maps have been published. Over 3,000 quadrangles in the United States have been surveyed, and maps of them similar to the one on the other side of this sheet have been published.

The topographic map is the base on which the geology and mineral resources of a quadrangle are represented, and the maps showing these features are bound together with a descriptive text to form a folio of the Geologic Atlas of the United States. More than 200 folios have been published.

Index maps of each State and of Alaska and Hawaii showing the areas covered by topographic maps and geologic folios published by the United States Geological Survey may be obtained free. Copies of the standard topographic maps may be obtained for 10 cents each; some special maps are sold at different prices. A discount of 40 per cent is allowed on an order for maps amounting to $5 or more at the retail price. The geologic folios are sold for 25 cents or more each, the price depending on the size of the folio. A circular describing the folios will be sent on request.

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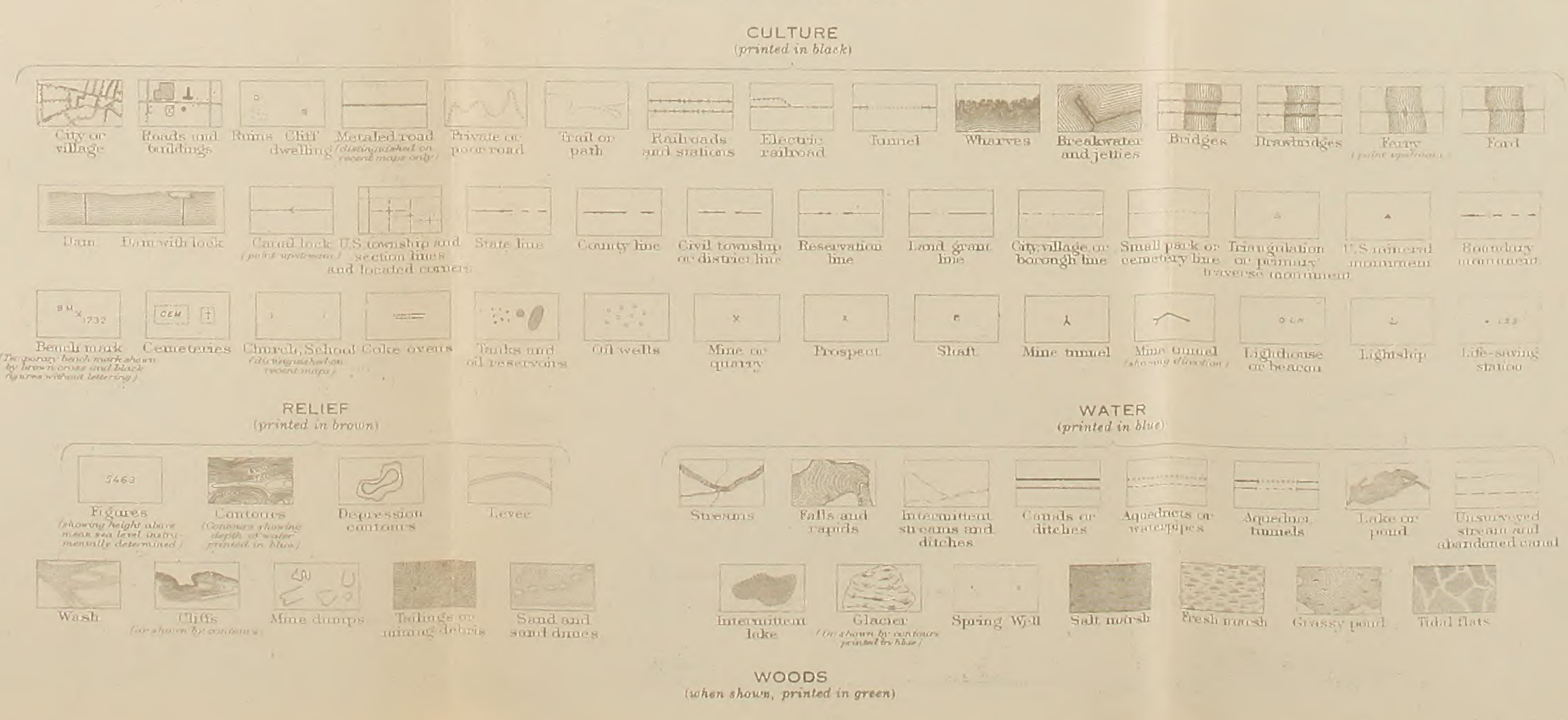
THE DIRECTOR,
United States Geological Survey,
Washington, D. C.

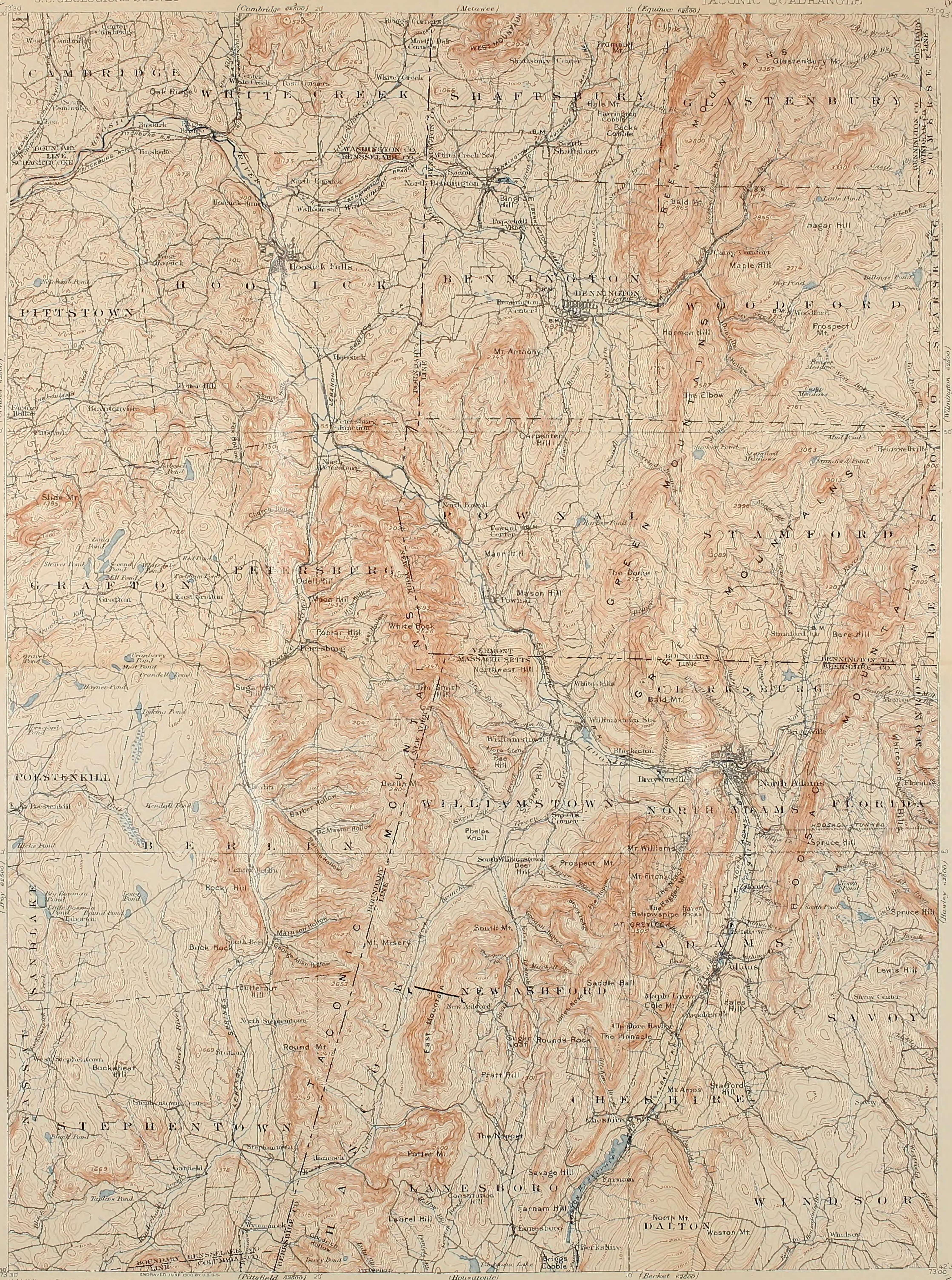
January, 1924.

CONVENTIONAL SIGNS



DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

NEW YORK - MASSACHUSETTS - VERMONT
TACONIC QUADRANGLE



H. M. Wilson, Geographer in charge.
Triangulation by the U.S. Coast and Geodetic Survey.
Borden Survey, S. S. Gannett and G. T. Hawkins.
Topography by W. D. Johnson, E. W. F. Natter, W. H. Lovell, R. D. Cummin, C. C. Bassett, J. H. Jennings, E. B. Clark, Jas. McCormick and A. M. Walker.
Surveyed in 1885, 1888, 1894 and 1896 in cooperation with the States of Massachusetts and New York.

Scale $\frac{1}{125000}$

Contour interval 40 feet.
Datum is mean sea level.

Edition of Nov. 1900, reprinted 1924.
Polyconic projection. North American datum.

TACONIC, NY-MASS-VT.

Map C

Taconic Mountains of New England

Myrtle L. Wilcock

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The standard scales used on these maps are multiples of the fraction $\frac{1}{1,000,000}$. Quadrangles in thickly settled or industrially important regions are mapped on a scale of $\frac{1}{62,500}$, or about 1 mile to an inch, and cover areas measuring 15′ in latitude and longitude. Quadrangles in less thickly settled or industrially less important districts are mapped on a scale of $\frac{1}{125,000}$, or about 2 miles to an inch, and cover areas measuring 30′ in latitude and longitude. Reconnaissance maps of desert or sparsely inhabited regions have been made on a scale of $\frac{1}{250,000}$, or about 4 miles to an inch, covering areas measuring 1° in latitude and longitude. Maps for special purposes are made on scales larger than $\frac{1}{62,500}$.

A topographic survey of Alaska has been in progress since 1898, and nearly 35 per cent of its area has now been mapped. About 10 per cent of the Territory has been covered by reconnaissance maps on a scale of $\frac{1}{625,000}$, or about 10 miles to an inch. Most of the remaining area surveyed in Alaska has been mapped on a scale of $\frac{1}{250,000}$, but about 3,500 square miles has been mapped on a scale of $\frac{1}{62,500}$.

A large part of the Hawaiian Islands has been surveyed, and the resulting maps are published on a scale of $\frac{1}{62,500}$.

The features shown on these maps may be arranged in three groups—(1) water, including seas, lakes, rivers, canals, swamps, and other bodies of water; (2) relief, including mountains, hills, valleys, and other features of the land surface; (3) culture (works of man), such as towns, cities, roads, railroads, and boundaries. The conventional signs used to represent these features are shown and explained below. Variations appear on some earlier maps, and additional features are represented on some special maps.

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Relief is shown by contour lines in brown. A contour line represents an imaginary line on the ground (a contour) every part of which is at the same altitude above sea level. Such a line could be drawn at any altitude, but in mapping only the contours at certain regular intervals of altitude are shown. The line of the seacoast itself is a contour, the datum or zero of altitude being mean sea level. The 20-foot contour, for example, would be the shore line if the sea should rise 20 feet. Contour lines show the shapes of the hills, mountains, and valleys, as well as their altitudes. Successive contour lines that are far apart on the map indicate a gentle slope; lines that are close together indicate a steep slope; and lines that run together indicate a cliff.

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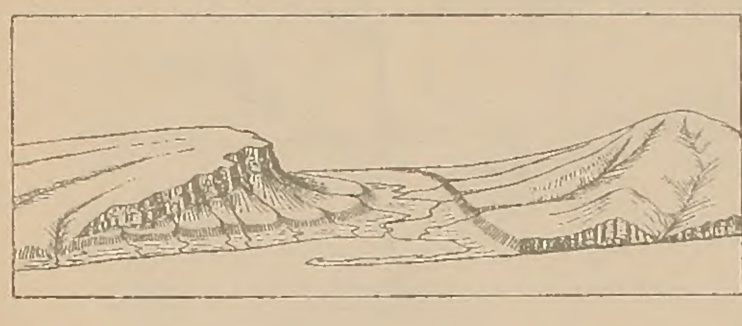

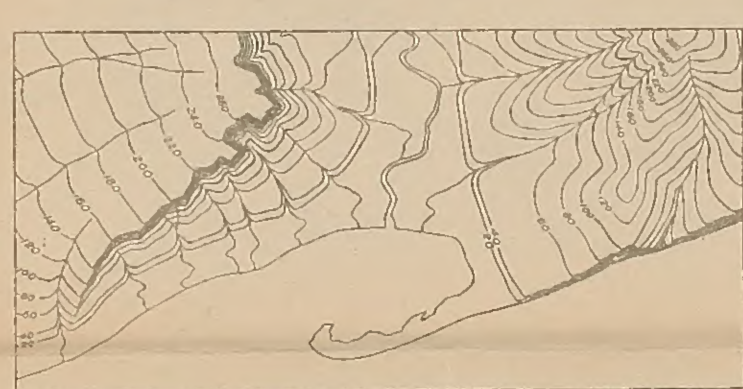

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THE DIRECTOR,
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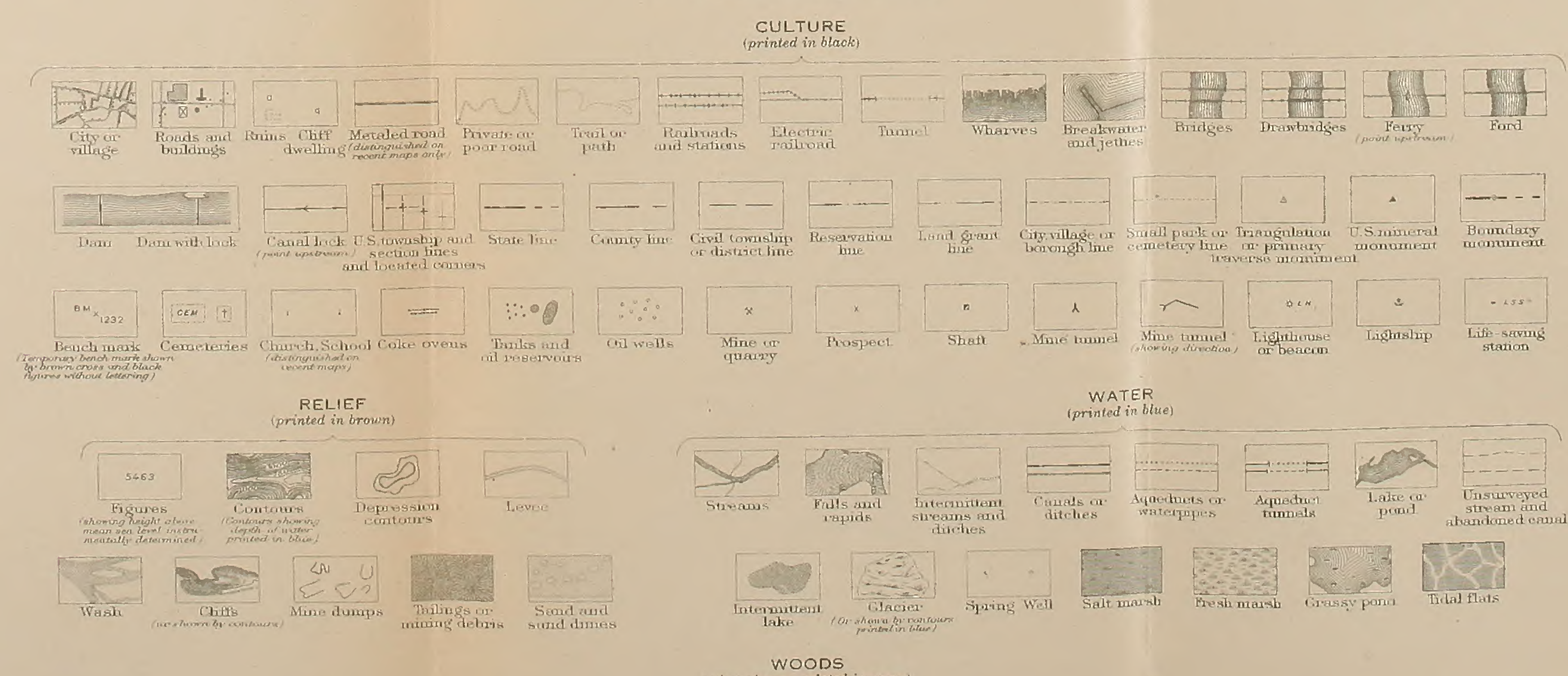
November, 1919.

CONVENTIONAL SIGNS



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DEPARTMENT OF THE INTERIOR
JOHN BARTON PAYNE, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

TOPOGRAPHY

MASS.-N.Y.-CONN.
HOUSATONIC QUADRANGLE

Henry Gannett, Chief Topographer.
Marcus Baker, Geographer in Charge.
Triangulation by U.S. Coast and Geodetic Survey,
Topography by Willard D. Johnson, E.W.F. Natter, W.H. Lovell,
with the States of Mass., N.Y. and Conn.

SUPPLIED BY
G. S. HAMMOND & CO.
MAP PUBLISHERS
30 CHURCH ST., NEW YORK, N.Y.

Scale $\frac{1}{125000}$

Contour interval 40 feet.
Datum is mean sea level.

Edition of Nov. 1900, reprinted 1920.

HOUSATONIC

Map D Taconic Mountains of New England Myrtle L. Wilcock

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The contour interval, or the vertical distance in feet between one contour and the next, is stated at the bottom of each map. This interval differs according to the topography of the area mapped: in a flat country it may be as small as 1 foot; in a mountainous region it may be as great as 250 feet. Certain contour lines, every fourth or fifth one, are made heavier than the others and are accompanied by figures showing altitude. The heights of many points—such as road corners, summits, surfaces of lakes, and bench marks—are also given on the map in figures, which show altitudes to the nearest foot only. More exact altitudes—those of bench marks—as well as the geodetic coordinates of triangulation stations, are published in bulletins issued by the Geological Survey.

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Each quadrangle is designated by the name of a city, town, or prominent natural feature within it, and on the margins of the map are printed the names of adjoining quadrangles of which maps have been published. Over 3,000 quadrangles in the United States have been surveyed, and maps of them similar to the one on the other side of this sheet have been published.

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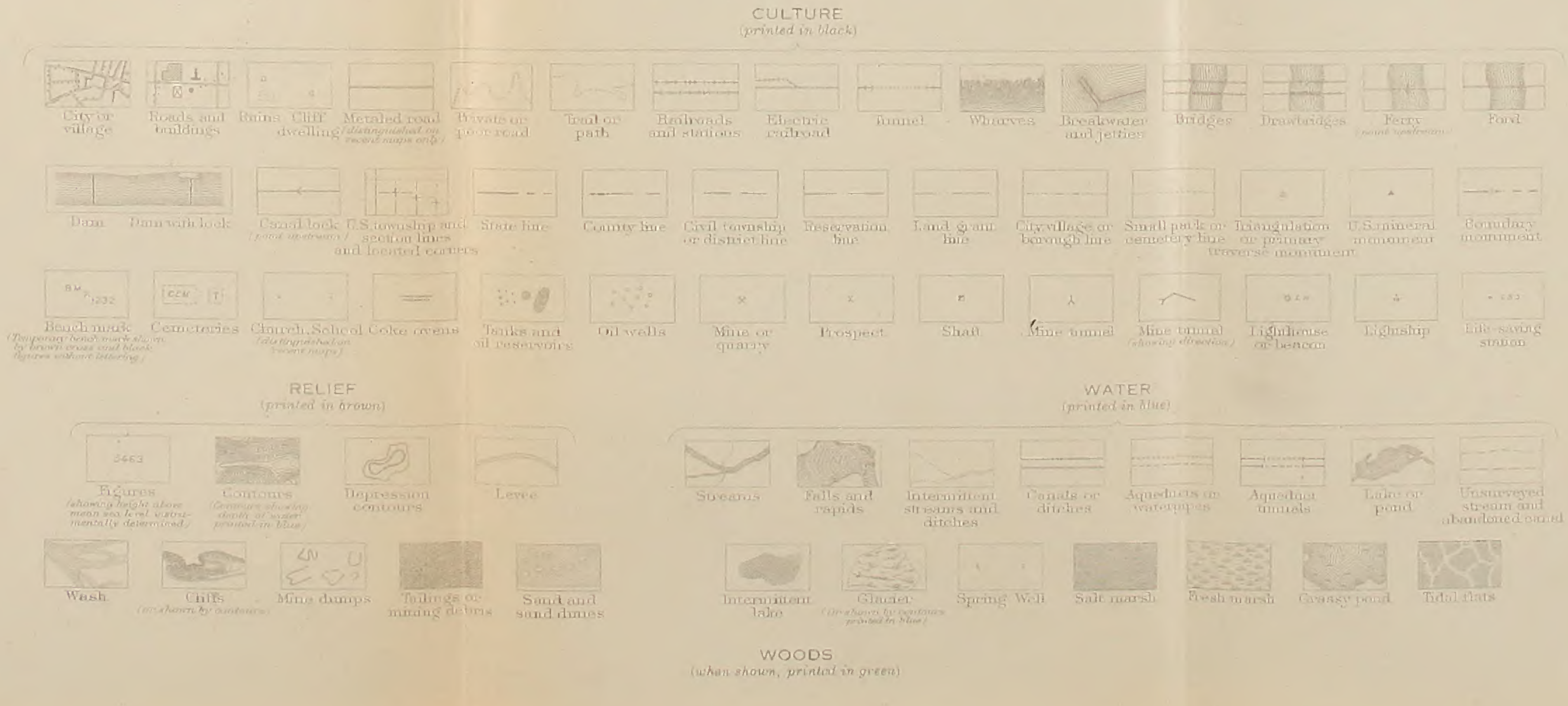
THE DIRECTOR,
United States Geological Survey,
Washington, D. C.

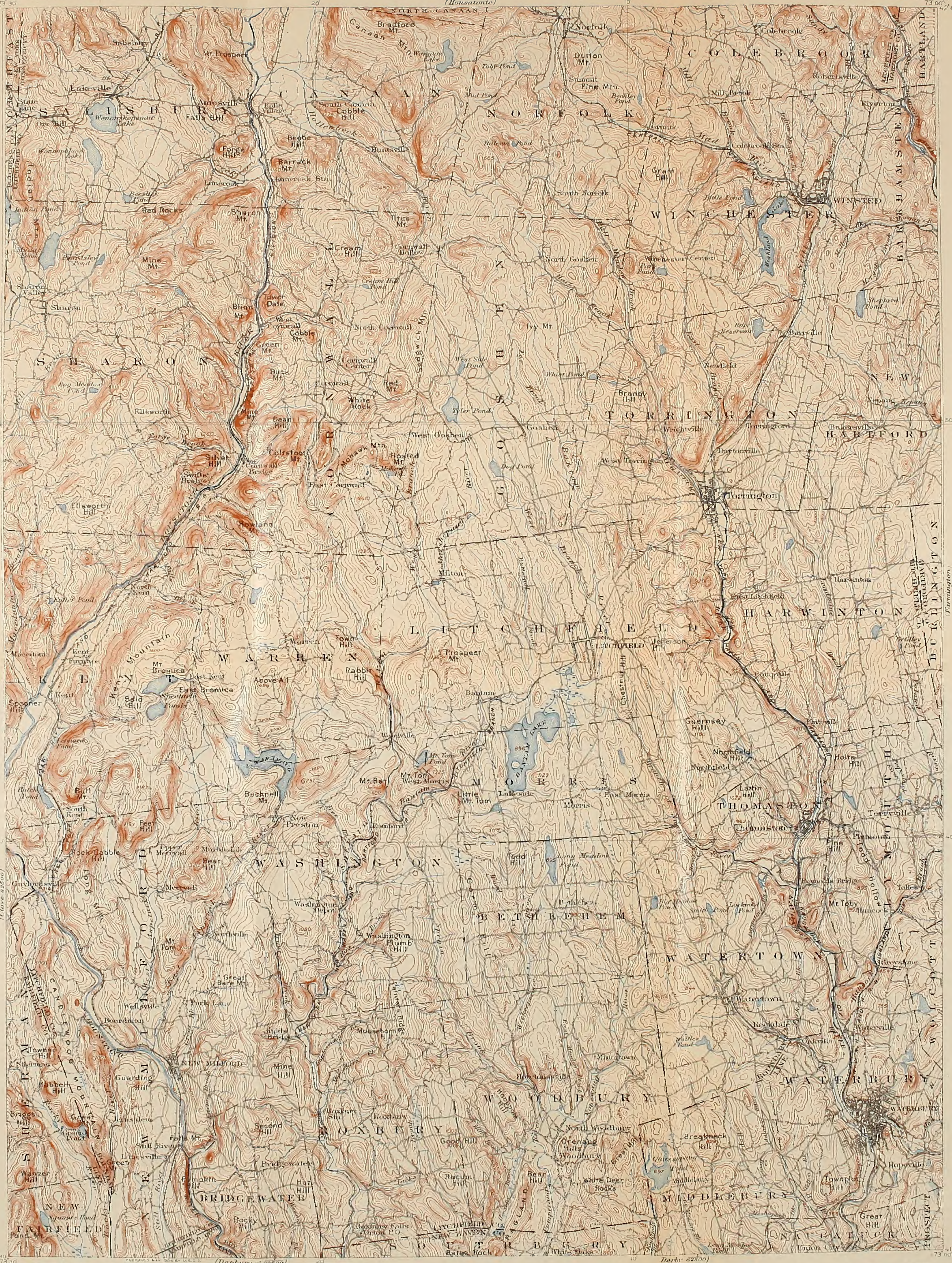
January, 1924.

CONVENTIONAL SIGNS



DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

CONNECTICUT - NEW YORK
LITCHFIELD QUADRANGLE



Henry Gannett, Chief Topographer.
Marcus Baker, Topographer in charge.
Triangulation by U.S. Coast and Geodetic Survey
Topography by E.W.F. Natter, J.H. Jennings,

SUPPLIED BY
C. S. HAMMOND & CO.
MAP PUBLISHERS
NEW YORK, N. Y.

SURVEYED IN 1889-1890 IN COOPERATION WITH THE STATE OF CONNECTICUT

APPROXIMATE MEAN DECLINATION 1903

Scale $\frac{1}{125000}$

5 Miles

5 Kilometers

Contour interval 40 feet.
Datum is mean sea level.

Edition of July 1904, reprinted 1923.
Polyconic projection. North American datum.

LITCHFIELD, CONN-NY

Map E Taconic Mountains of New England Myrtle L. Wilcock

THE TOPOGRAPHIC MAPS OF THE UNITED STATES

The United States Geological Survey is making a standard topographic atlas of the United States. This work has been in progress since 1882, and its results consist of published maps of more than 40 per cent of the country, exclusive of outlying possessions.

This topographic atlas is published in the form of maps on sheets measuring about 16½ by 20 inches. Under the general plan adopted the country is divided into quadrangles bounded by parallels of latitude and meridians of longitude. These quadrangles are mapped on different scales, the scale selected for each map being that which is best adapted to general use in the development of the country, and consequently, though the standard maps are of nearly uniform size, they represent areas of different sizes. On the lower margin of each map are printed graphic scales showing distances in feet, meters, and miles. In addition, the scale of the map is shown by a fraction expressing a fixed ratio between linear measurements on the map and corresponding distances on the ground. For example, the scale $\frac{1}{62,500}$ means that 1 unit on the map (such as 1 inch, 1 foot, or 1 meter) represents 62,500 similar units on the earth's surface.

Although some areas are surveyed and some maps are compiled and published on special scales for special purposes, the standard topographic surveys for the United States proper and the resulting maps have for many years been divided into three types, differentiated as follows:

1. Surveys of areas in which there are problems of great public importance—relating, for example, to mineral development, irrigation, or reclamation of swamp areas—are made with sufficient accuracy to be used in the publication of maps on a scale of $\frac{1}{31,680}$ (1 inch = one-half mile), with a contour interval of 1, 5, or 10 feet.

2. Surveys of areas in which there are problems of average public importance, such as most of the basin of the Mississippi and its tributaries, are made with sufficient accuracy to be used in the publication of maps on a scale of $\frac{1}{62,500}$ (1 inch = nearly 1 mile), with a contour interval of 10 to 25 feet.

3. Surveys of areas in which the problems are of minor public importance, such as much of the mountain or desert region of Arizona or New Mexico, are made with sufficient accuracy to be used in the publication of maps on a scale of $\frac{1}{125,000}$ (1 inch = nearly 2 miles), with a contour interval of 25 to 100 feet.

A topographic survey of Alaska has been in progress since 1898, and nearly 37 per cent of its area has now been mapped. About 10 per cent of the Territory has been covered by reconnaissance maps on a scale of $\frac{1}{625,000}$, or about 10 miles to an inch. Most of the remaining area surveyed in Alaska has been mapped on a scale of $\frac{1}{250,000}$, but about 4,000 square miles has been mapped on a scale of $\frac{1}{62,500}$.

About half of the Hawaiian Islands has been surveyed, and the resulting maps are published on a scale of $\frac{1}{62,500}$.

The features shown on these maps may be arranged in three groups—(1) water, including seas, lakes, rivers, canals, swamps, and other bodies of water; (2) relief, including mountains, hills, valleys, and other features of the land surface; (3) culture (works of man), such as towns, cities, roads, railroads, and boundaries. The conventional signs used to represent these features are shown and explained below. Variations appear on some earlier maps, and additional features are represented on some special maps.

All the water features are represented in blue, the smaller streams and canals by single blue lines and the larger streams, the lakes, and the sea by blue water lining or blue tint. Intermittent streams—those whose beds are dry for a large part of the year—are shown by lines of blue dots and dashes.

Relief is shown by contour lines in brown, which on some maps are supplemented by shading showing the effect of light thrown from the northwest across the area represented, for the purpose of giving the appearance of relief and thus aiding in the interpretation of the contour lines. A contour line represents an imaginary line on the ground (a contour) every part of which is at the same altitude above sea level. Such a line could be drawn at any altitude, but in practice only the contours at certain regular intervals of altitude are shown. The line of the seacoast itself is a contour, the datum or zero of altitude being mean sea level. The 20-foot contour would be the shore line if the sea should rise 20 feet. Contour lines show the shape of the hills, mountains, and valleys, as well as their altitude. Successive contour lines that are far apart on the map indicate a gentle slope; lines that are close together indicate a steep slope; and lines that run together indicate a cliff.

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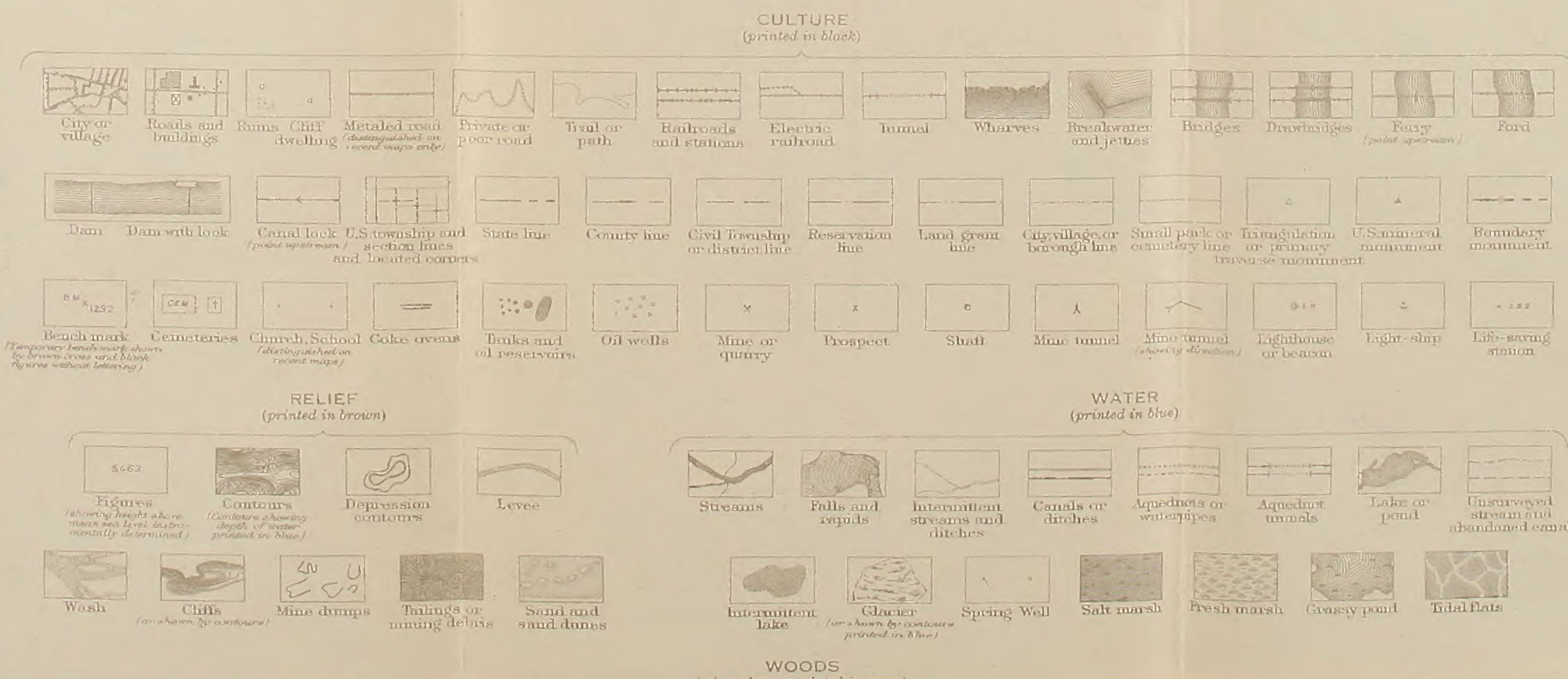
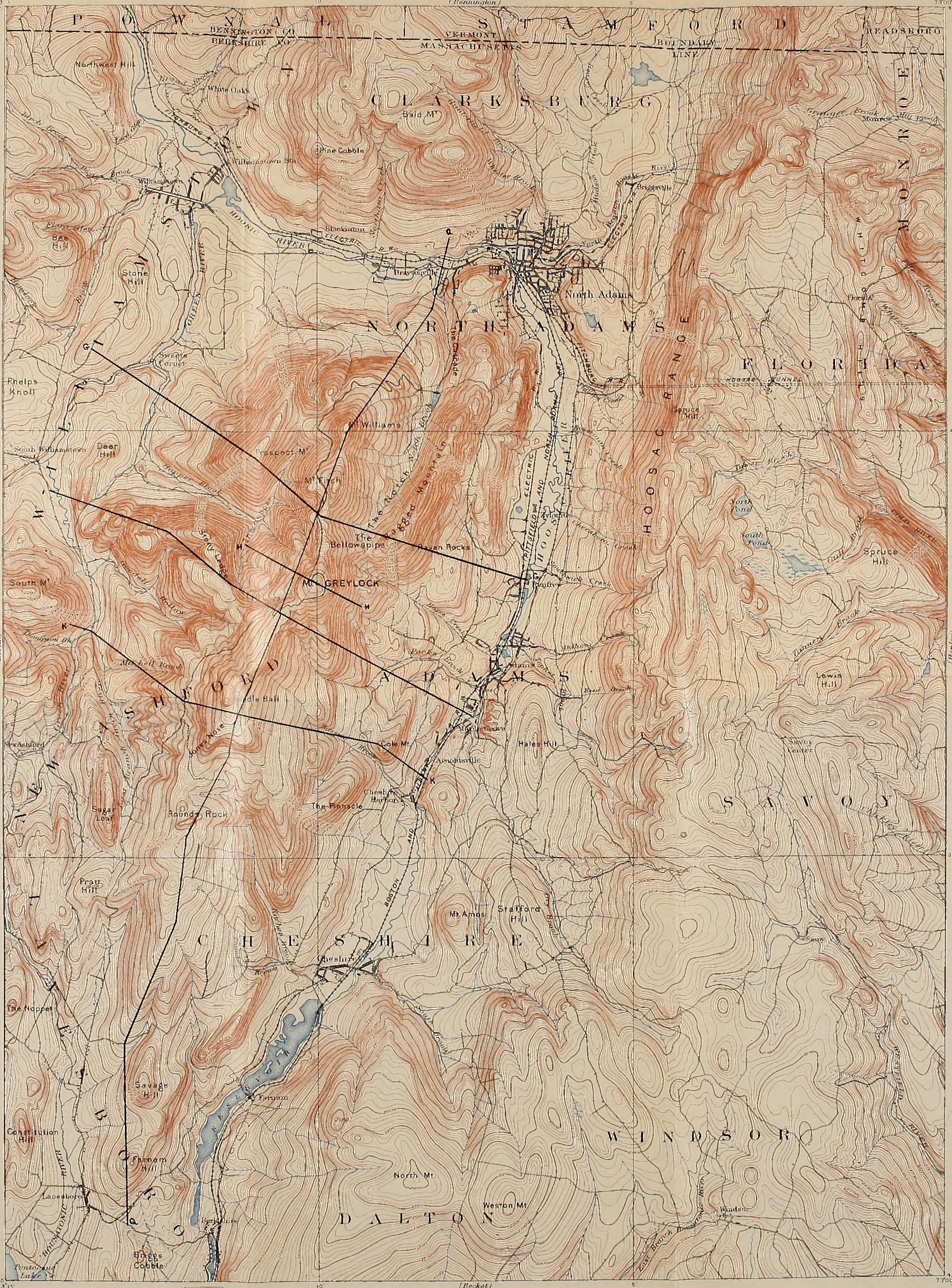


DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MASSACHUSETTS-VERMONT
GREYLOCK SHEET



(Pittsfield) (Becket) (Chesterfield)

Henry Gannett, Chief Geographer
Triangulation by the U.S. Coast and Geodetic and Borden Surveys
Topography by W.D. Johnson, R.D. Cummin and W.H. Lovell
Surveyed in 1885 in cooperation with the state of Mass.

Johnson | Cummin | Lovell

Scale $\frac{1}{62500}$

Miles

Kilometers

Contour interval 20 feet

Datum is mean sea level.

Edition of Nov. 1898, reprinted 1925.

Polyconic projection, North American datum

GREYLOCK, MASS.-VT.

MAPS

TACONIC MOUNTAINS OF NEW ENGLAND

MYRTLE L. WILCOCK